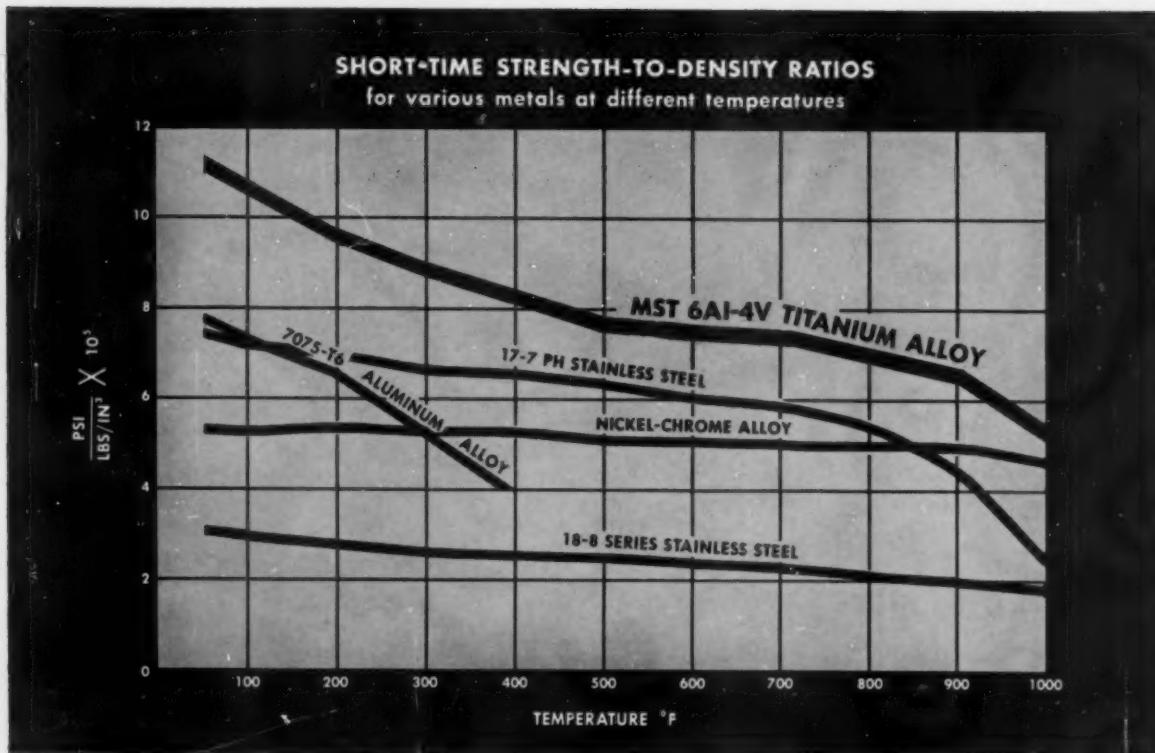


Progress with **TITANIUM**



## **TITANIUM ON TOP**

in medium-high temperature range

Today's most popular titanium alloy, MST 6Al-4V, excels all other metals in strength to density ratio through 900°F. At room temperature, considering only strength, a part made of this alloy need have only 60% of the weight of the equivalent part in stainless steel.

Performance for extended times at elevated temperatures is likewise good. In typical creep tests, with 1% permanent deformation allowed, MST 6Al-4V alloy shows 100,000 psi allowable stress at 750°F for 1 hour; 77,000 psi at 100 hours; 65,000 psi at 1000 hours.

Meanwhile new alloys extending the elevated temperature usefulness of titanium—to as high as 1000°F—are now emerging from the laboratory into production.

Write Dept. F-7 for copy of "Titanium Alloy Properties"

### **SELECTION GUIDE TO MST ALLOYS**

*Typical Mechanical Properties of Annealed Titanium and its Alloys*

|                                   | Form       | Ultimate Tensile Strength, psi | Yield Strength, psi | Elongation, %* |
|-----------------------------------|------------|--------------------------------|---------------------|----------------|
| <b>COMMERCIALLY PURE TITANIUM</b> |            |                                |                     |                |
| MST Grade III . . . . .           | Sheet, Bar | 70,000                         | 50,000              | 25             |
| (3 different strength levels)     | Sheet, Bar | 85,000                         | 65,000              | 23             |
|                                   | Sheet, Bar | 100,000                        | 80,000              | 20             |
| <b>TITANIUM ALLOYS</b>            |            |                                |                     |                |
| <b>MST 6Al-4V</b>                 |            |                                |                     |                |
| Annealed . . . . .                | Bar        | 140,000                        | 130,000             | 15             |
| Age hardened (1) . . . . .        | Bar        | 165,000                        | 155,000             | 12             |
| Age hardened (2) . . . . .        | Bar        | 180,000                        | 165,000             | 10             |
| Annealed . . . . .                | Sheet      | 140,000                        | 125,000             | 12             |
| <b>MST 3Al-5Cr . . . . .</b>      | Bar        | 155,000                        | 145,000             | 13             |
| <b>MST 4Al-4Mn . . . . .</b>      | Bar        | 150,000                        | 140,000             | 14             |
| <b>MST 8 Mn . . . . .</b>         | Sheet      | 137,000                        | 125,000             | 16             |

(1) 1650°F—1 hour—WQ; 1100°F—2 hours—AC      WQ—Water Quench

(2) 1700°F—1 hour—WQ; 1000°F—8 hours—AC      AC—Air Cool

\* Values for 1" on bar and 2" on sheet

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# Metal Progress

Volume 72, No. 1

July . . . 1957

HAROLD J. ROAST  
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ERNEST E. THUM, *Editor*

MARJORIE R. HYSLOP, *Managing Editor*

FLOYD E. CRAIG  
*Art Director*

DAVE RITCHIE  
*Assistant Editor*

The Dali-esque metallograph on the front cover by  
BARBARA FENWICK won a "special award" in A.S.M.'s  
annual competition at Cleveland Institute of Art.

## Heating Methods for Modern Brazing Operations . . . . . 65

Some observations about the brazing method (fits, assembly, cleanliness and alloys) are followed by specific information about three methods of heating for mass production: in furnaces with protective atmospheres or vacuum, in molten salt baths, and rapid heating in air by high-frequency electric currents. (K8j, K8k, K8n, 1-2)\*

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## Induction Brazing, by Wm. E. Benninghoff . . . . . 74

## Industry's New Silent Partner - Industrial TV, by Don Post . . . . . 78

An industrial TV camera, broadcasting through a coaxial cable to a 17-in. receiver, reports more accurately and efficiently on the state of a process than the human being it replaces. (S general, X15p; Al, 7-1)

## Metallurgists Needed Badly . . . . . 80A

Take this insert out and give it to some bright boy who is still in high school or who has just graduated. Also try to sell him on your profession. (A2)

## Titanium Tubing, by Thomas M. Krebs . . . . . 82

Seamless titanium tubing is available in a wide range of sizes in A-40, A-55 or A-70 grades with extruded and ground or machined surfaces or cold finished. Welded and cold finished tubing is also available. Alloy tubing may be obtained in the extruded and heat treated condition. The outstanding resistance of titanium to many chemicals, such as chlorides, indicates a large future use in the chemical and process industries. (F24, F26, T general; Ti, 4-10)

## Criteria for Evaluating Electrical Resistance Alloys, by C. Dean Starr . . . . . 88

Even though the "life" of Ni-Cr and Ni-Cr-Fe resistors, as measured by standard test, has been increased tenfold in the past 30 years, the industry is still improving the older standardized analyses, and seeking new varieties of Ni-Cr-Al, Fe-Cr-Al and molybdenum-base alloys for more severe services. (S21, Q general, 2-12; SGA-q)

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RESEARCH



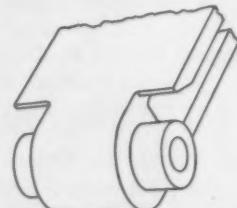
\*The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, Revised Edition, 1957



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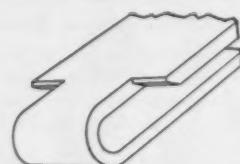


Typical heavy-duty link with cast pin.

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\*Reg. U. S. Pat. Off.



Typical 3" or 4" pitch center link of loop-type casting design.

#### WRITE FOR BULLETIN T-241

... giving additional design and application information on both Heavy-Duty and General-Purpose Thermalloy Conveyor Belts. Address: Electro-Alloys Division, 8037 Taylor St., Elyria, Ohio.

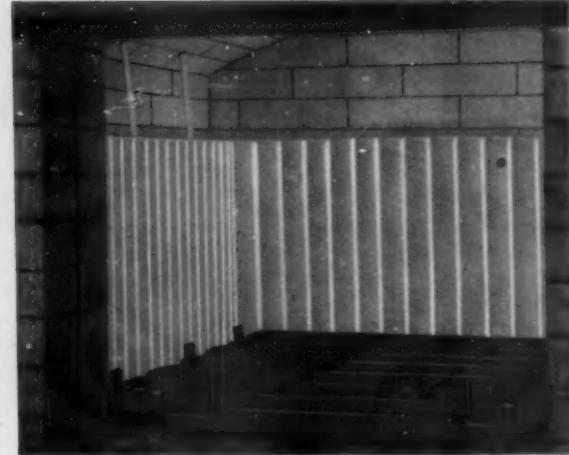


**ELECTRO-ALLOYS DIVISION** ELYRIA, OHIO

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METAL PROGRESS

# As I was saying...



MY TRAVEL REQUIREMENTS are very heavy so I depend on my capable Miss Friday for information from the Cleveland front. Here is the latest:

DEAR BOSS: You had a call from the architects, stating they'll meet you as planned on the 11th. They hope the new approach to the headquarters building will please the committee and the cost will be "in the ball park".

Mr. Thum was in New York Friday for a meeting of the AEC Advisory Committee on Industrial Information of which he is chairman. He says he is still looking for an associate editor to replace John Tyrrell.

Marjorie Hyslop returned from New London and Boston where she gave a talk on documentation of metallurgical lit. It's the third time she has been invited to present the findings.

I know how pleased you were when Marjorie and Mr. Thum were requested to appear before the Defense Department in Washington and explain A.S.M.'s five-year research program on mechanized searching at Western Reserve.

Ray Bayless has been able to secure a two-year lease on 2300 sq.ft. of additional office space near 7301 Euclid. It will be ready in 30 days — and it's just in time because today's mail brought acceptances from the two young men you interviewed to join Dr. Brasunas in the Metal Engineering Institute.

When M.E.I. moves to the new spot the present 65 employees will be able to breathe comfortably again for a while at least. We really need our new building! I hope they can cut down the time schedule. Even after a design has been accepted, I understand the architects require about a year to make the working drawings and secure contractors, and then another year is needed for construction of the building.

John Parina likes his new work as book editor and says we have ten manuscripts on hand and six more coming in at convention time.

Mr. Wells is highly pleased at the early requests for space in the new Southwestern Metal Congress and Exposition (Dallas, May 12-16, 1958). Also he tells me the Chicago show is getting larger every day.

Kingsley Given is certainly a great help in the Second World Metallurgical Congress. He asked me for the list of American counterparts (will need about five or six hundred) so you may wish to give it some thought.

Dr. Lyman just returned from a west coast meeting with the airframe industry and said to tell you the entire industry has approved the project A.S.M. is doing for the Air Materiel Command and will cooperate 100%.

Howard Boyer, the new managing editor of A.S.M. Metals Handbook, is happily at work and said he hopes to have the first volume of the new edition at the print shop in about nine months.

Mr. Ford sends word that the July issue of M.P. will carry 25% more advertising this year than in 1956.

We were glad to hear that you had decided to entertain the entire Second World Metallurgical Congress touring groups (some 400) at an "Early American Party" at your Sunnimoor Farm in October. Seward Covert (P.R. 2nd WMC) told me the "Indians" have already agreed to entertain again.

Excuse me, I've other things to do, so "so long for a while".

EVELYN

So there you are! The plant works just as well and successfully as if I'm in the front office — and you all know why — everyone is dedicated to his or her part in making the A.S.M. of Today and the A.S.M. of Tomorrow vital and important factors in the rapid development of the great metals industries of America.

Cordially,

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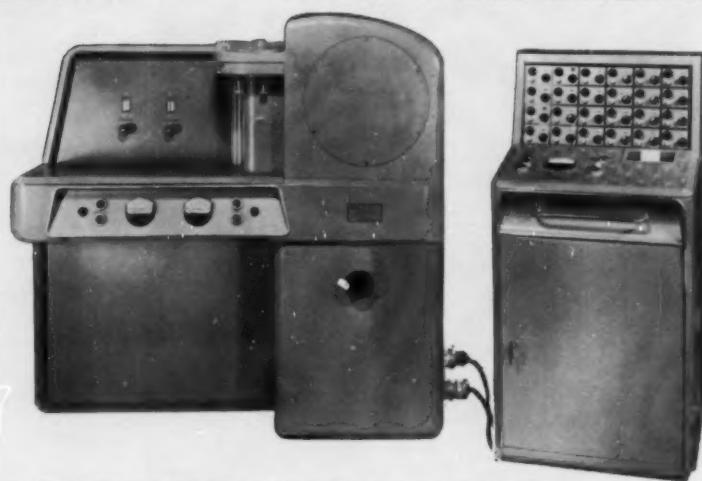
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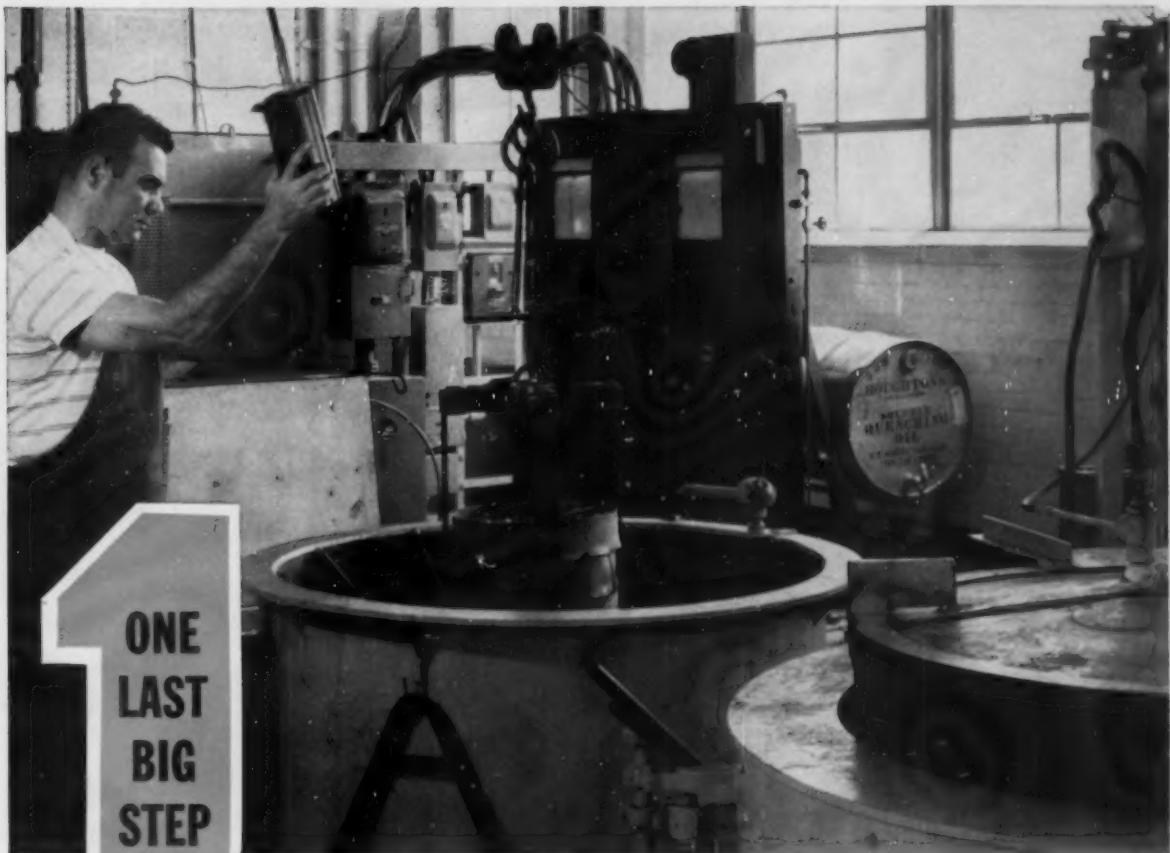
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Mr. Robert C. Sermon (seated), President, and Mr. Elmo Tellone (center), Vice President, of X-Ray Engineering Company, discuss the advantages of Du Pont 506 Film with R. L. McCallister, Du Pont Technical Representative.



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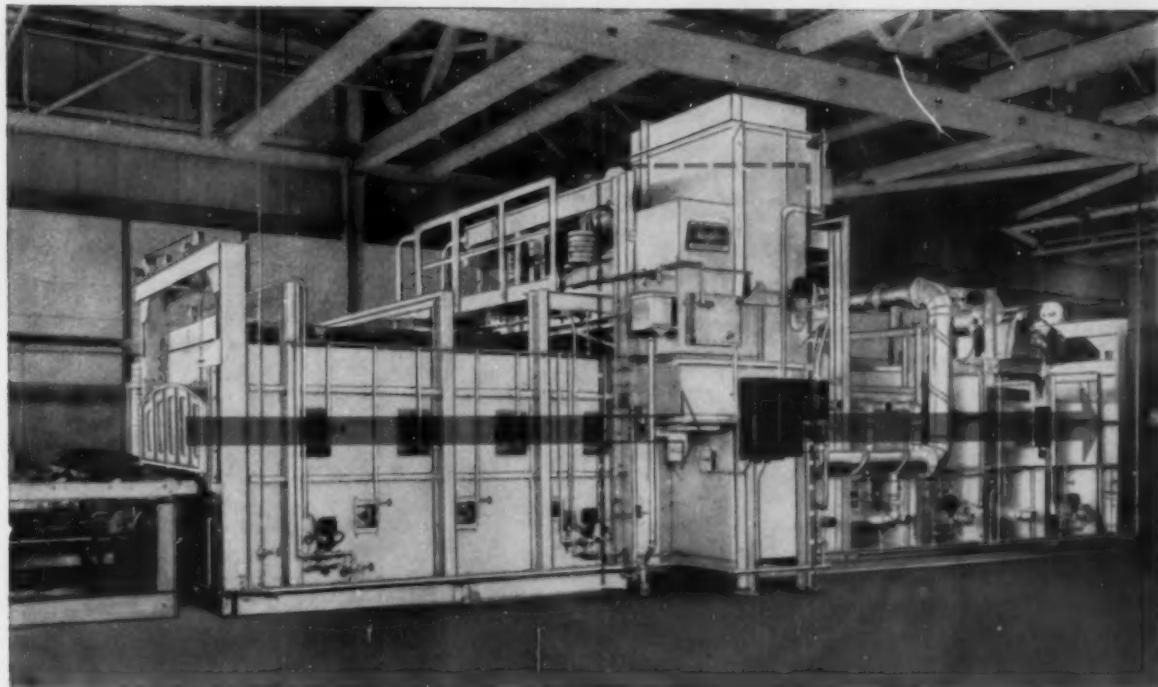
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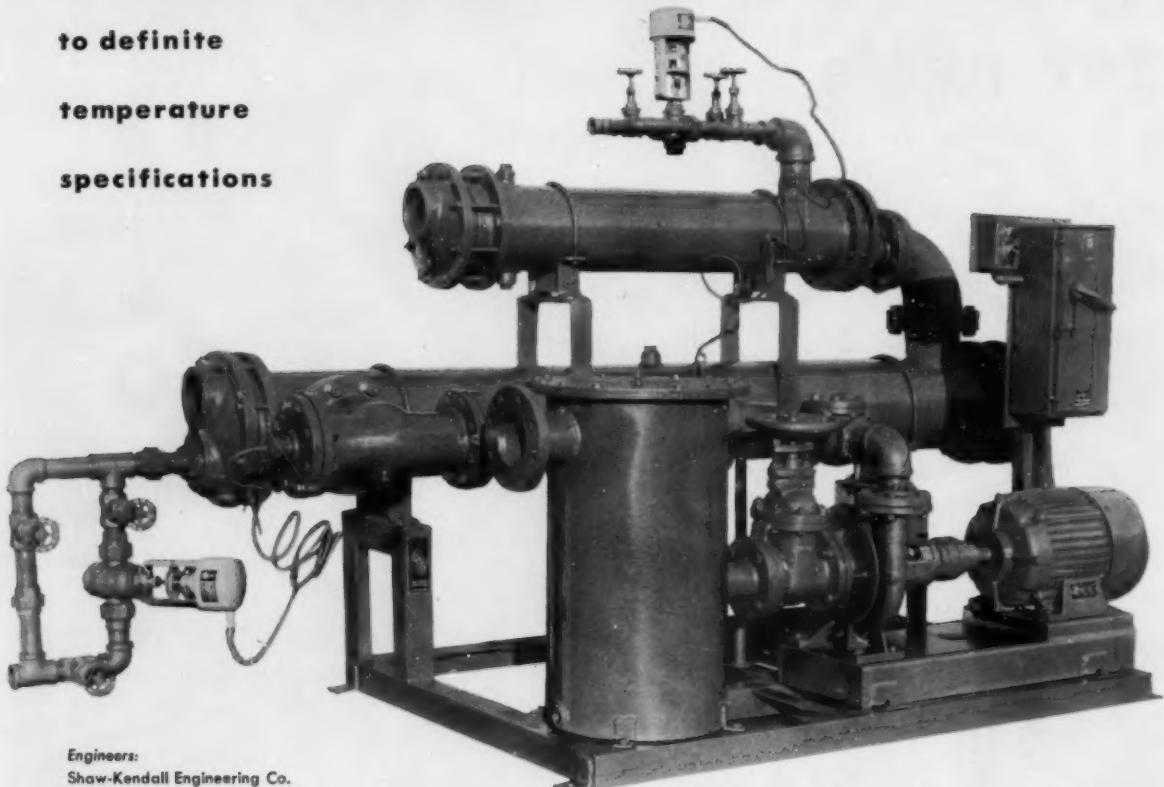
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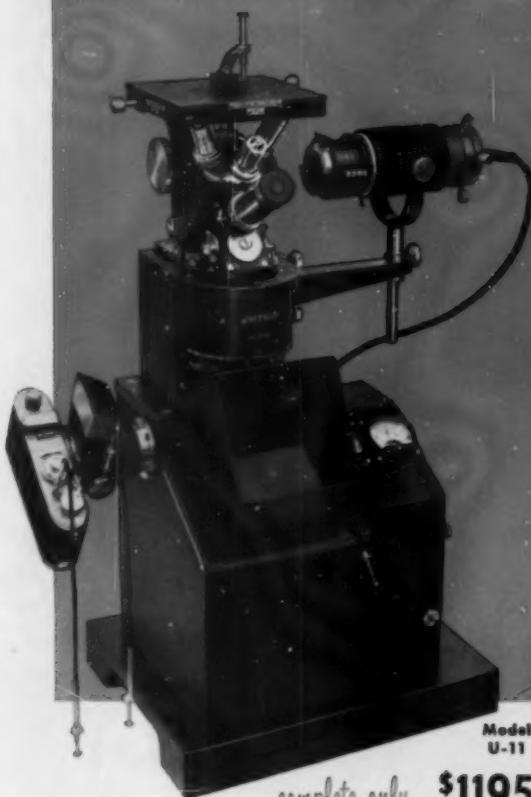
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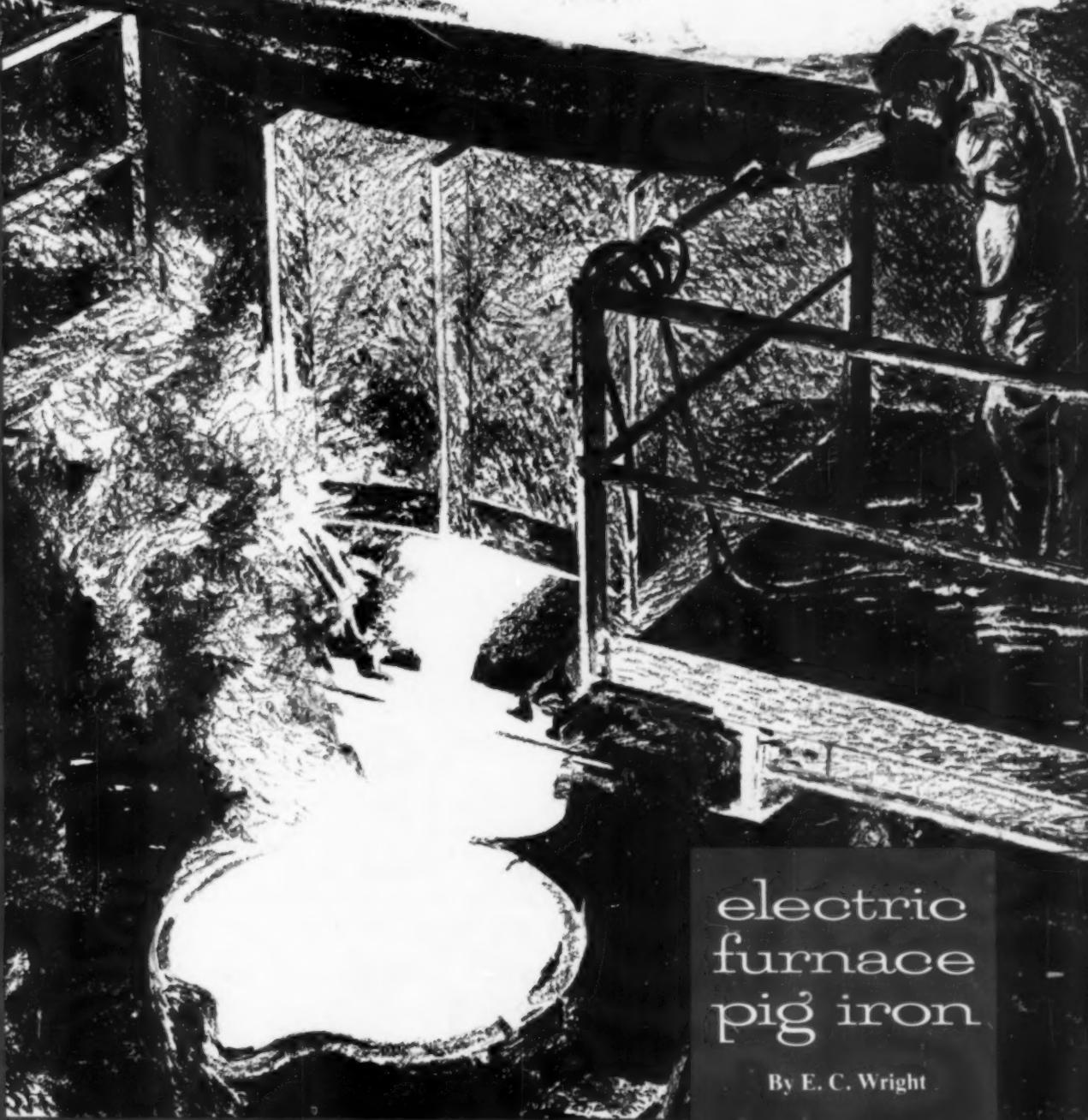
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# CARBON AND GRAPHITE NEWS



electric  
furnace  
pig iron

By E. C. Wright



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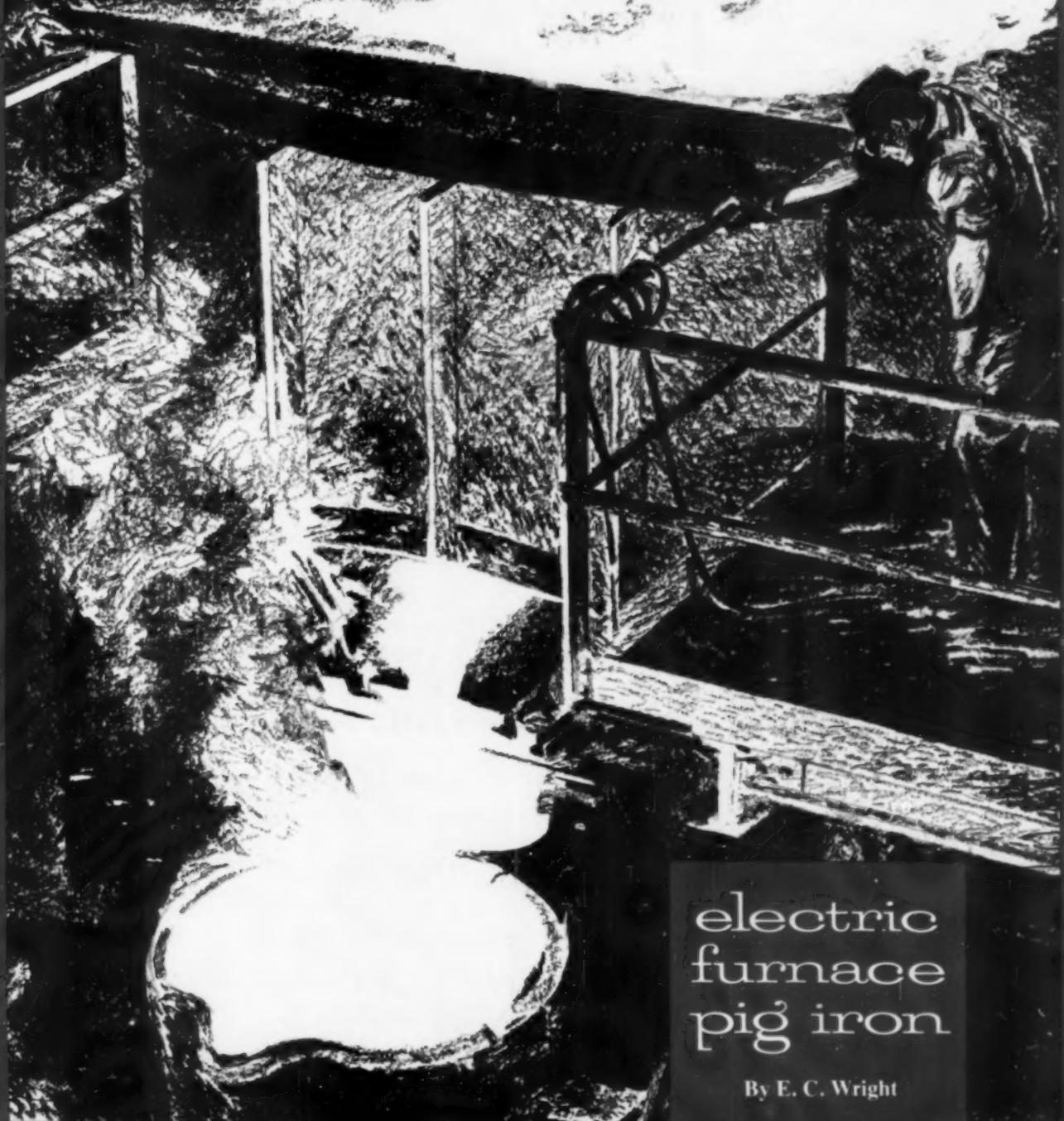
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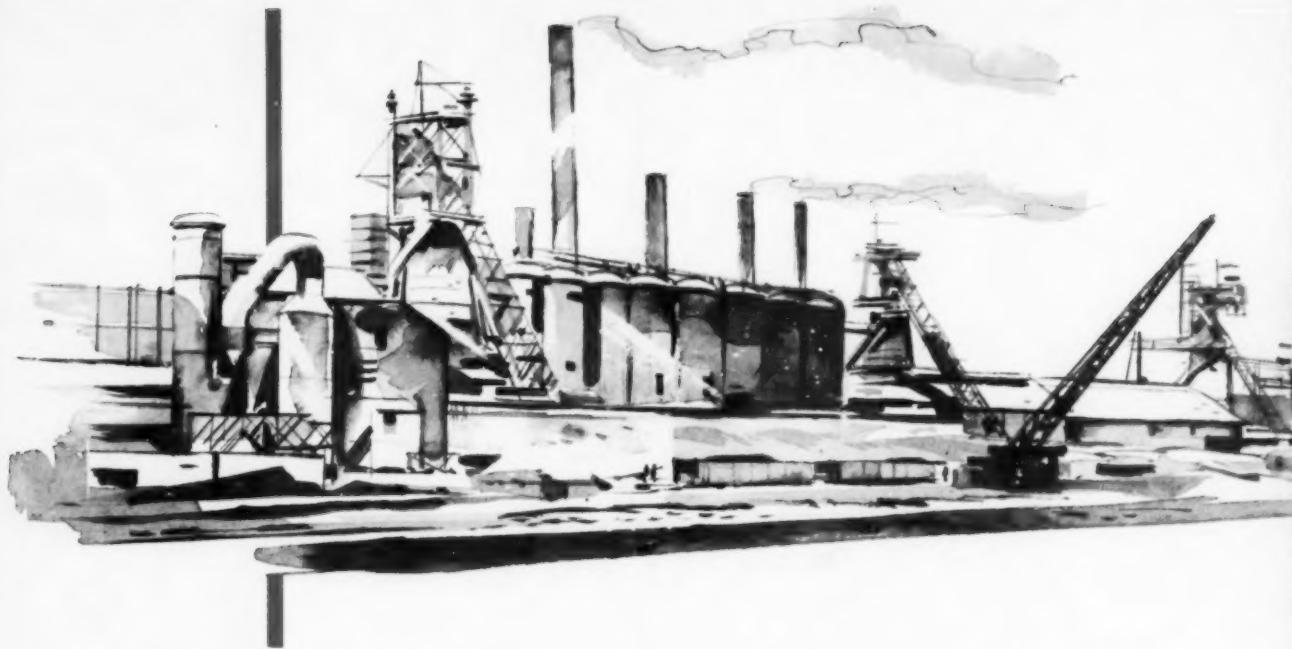
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# CARBON AND GRAPHITE NEWS



electric  
furnace  
pig iron

By E. C. Wright



## **Current Technical and Economical Factors Affecting the Steelmaking Process**

- Great increases in freight rates which affect the cost of assembling raw materials.
- Large increases in cost of mining coal and ore.
- High cost of steel scrap.
- Use of cheap oxygen for desiliconizing hot metal for open hearth or electric furnaces.
- Large increases in the use of high grade (over 60% Fe) imported iron ores.
- Use of concentrated magnetite ores which are upgraded to over 60% Fe.
- Complete pre-preparation of blast furnace charge involving accurate sizing of coke, stone, and ore particles including sintered or pelletized iron ore concentrates and complete elimination of all fines from the charge.
- Use of pre-reduced iron ore for electric furnace pig iron smelting at significantly lower power inputs than prevail abroad.



# electric furnace pig iron

By E. C. Wright

Head, Department of  
Metallurgical Engineering  
University of Alabama  
University, Alabama



Many new technical and economic factors have developed in the past five years which may have an important bearing upon determining the best process to use for making steel at various locations in the United States. Some of the most important of these are cost factors—items such as substantial freight rate increases affecting the cost of assembling raw materials, high cost for steel scrap, sizeable increases in mining costs for coal and ore and the use of cheap oxygen in desiliconizing hot metal for open hearth or electric furnaces. Other important factors are technological in nature. Typical items in this category involve the use of concentrated magnetic ores upgraded to over 60% Fe, large increases in use of high grade (over 60% Fe) imported iron ores, and the use of pre-reduced iron ore for electric furnace pig iron smelting at significantly lower power inputs than prevail abroad. Also, the complete pre-preparation of blast furnace charge involving accurate sizing of coke, stone, and ore particles including sintered or pelletized iron ore concentrates and complete elimination of all fines from the charge.

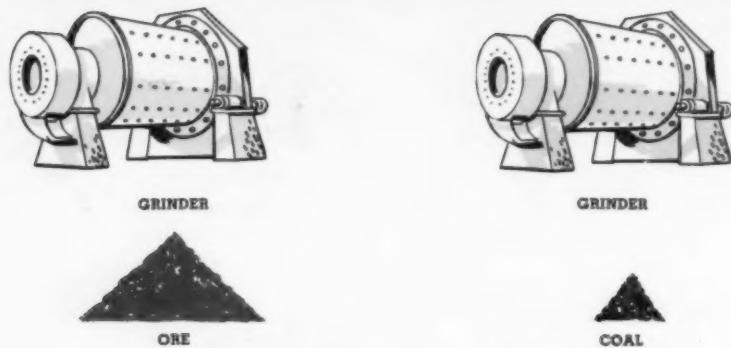
## Two Important Results

At the present time the impact of these developments seems to indicate two important results:

(1) The increased use of higher grade ores or concentrates and fully prepared uniform blast furnace burden will obviously increase blast furnace output per day, decrease coke rate, flux requirements, slag volume, capital charges and overhead on the cost of producing hot metal. These factors will decrease the cost of hot metal based on present costs of raw materials and will greatly benefit fully integrated plants which have ample blast furnace capacity. If these conditions prevail, the future expansion of steel output will be based on increases in blast furnace capacity and greater use of hot metal as compared to cold scrap. Technical improvements indicate such a conclusion but the economics of the relative cost of steel scrap and iron ore will determine the outcome at any given period. Decreasing melt time by means of faster charging, higher blast furnace hot metal charges, desiliconizing blast furnace hot metal or blowing the bath with oxygen at integrated plants will reduce the cost above material as most of the items included in these costs represent an hourly cost which is inversely proportional to the rate of production. The fully integrated plant will thus benefit by new practices in both the blast furnace and open hearth or electric furnace stages and this will increase the favorable cost differential over the cold metal melt shops as long as steel scrap remains over \$40 per net ton.

(2) Steel production from cold steel scrap melts at non-integrated open hearth or electric furnace plants

## Five Basic Steps of Direct Reduction by Electrics



will be more costly than charges containing over 40% hot metal whenever the price of scrap is over \$40 per net ton. The 1956 Directory of the Iron & Steel Institute showed about 73 electric furnaces of 30 to 150 ton capacity at non-integrated plants where no hot metal is available. At the Electric Steel Conference at Chicago in December, 1956, there was much discussion of the high cost scrap problem among non-integrated electric steel producers and four papers were presented which described the substitution of other iron bearing materials for cold steel scrap. At that time, the Iron Age composite price was \$59 per net ton. Some of the papers discussed the direct reduction of high grade iron ores by the electric furnace method, hydrogen reduced iron (H-iron), Swedish sponge iron, additions of ordinary hot metal, and/or the use of desiliconized hot metal as substitutes for all or part of the steel scrap in the charge. Electric furnace direct reduction is an economical method of supplementing blast furnace hot metal at integrated plants, and is also an economical method for making hot metal available to present non-integrated plants.

### Direct Reduction By Electrics

The introduction of pelletizing for the processing of fine ores and concentrates has led to some odd new developments. Mineral pellets are made by rolling finely divided minerals with accurate amounts of water in balling drums or rotating discs. Balls or pellets of various sizes are produced in a very wet state and these must be dried and then fired to a high temperature to heat harden the pellets. Usually fine coal (1-2%) is incorporated in the pellet to supply the necessary fuel for the heat hardening process. This yields a strong pellet in the highly oxidized state. Several engineers have found that additions of coal approaching 25% of the pellet weight will not only develop a hard, strong pellet, but also pre-reduce much of the  $Fe_2O_3$  or  $Fe_3O_4$  in the pellet to  $FeO$  or metallic iron. Furthermore, hot pre-reduced pellets (above 1600°F) may be discharged directly into a submerged arc electric smelting furnace and produce hot metal directly from the pre-reduced pellets with a great saving in electric power.

Calculations indicate that a 32 ft. diameter furnace, 45 inch pre-baked carbon electrodes, and

20,000 KVA available power will produce 400 tons of hot metal per day at a cost of \$45 or less per net ton. Very low sulphur pig iron is made in a basic lined furnace. The equipment needed for such an installation is mainly:

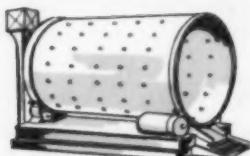
1. Grinding and Blending machinery for mixing the ore, coal and limestone.
2. Pelletizing Equipment.
3. Sintering machine or vertical shaft furnace for the heat hardening and pre-reduction of pellets.
4. Submerged arc smelting furnace for making hot metal.

### Economic Advantages

The direct reduction of high grade iron in submerged arc smelting furnaces is widely practiced in several foreign countries where the cost of coal and coke is high. Foreign plant operations consume about 2270 KW hours per net ton. Developments in the United States make it possible to produce electric pig iron at roughly  $\frac{1}{2}$  the KWH per ton consumption of foreign plants.

Estimates indicate an investment in the neighborhood of \$6,000,000 should cover the installation of a 400 to 500 ton per day unit. Based on 8000 hours per year operating time the investment cost will approximate \$40 per annual pig iron ton which is somewhat less than that of a complete blast furnace, coke plant and accessories. It is obvious that as long as steel scrap remains above \$45.00 per net ton, the substitution of molten hot metal at \$45.00 per ton or less would be an asset to a cold scrap electric furnace plant for either carbon steel or alloy steel heats. The use of high grade foreign ores or concentrates containing over 60% Fe would also lower the cost of this operation by decreasing slag volume, fluxes and power required on the electric furnace. This new process thus suggests a way out of the present economic difficulty which has arisen to plague all cold scrap melting operations as a result of widely fluctuating scrap prices; it also enables a small non-integrated melt shop or foundry to obtain 400 tons per day of molten hot metal without facing the very high investment cost encountered in the construction of a modern blast furnace plant.

Another advantage of this hot metal supply is that it could be cheaply desiliccnized with oxygen and



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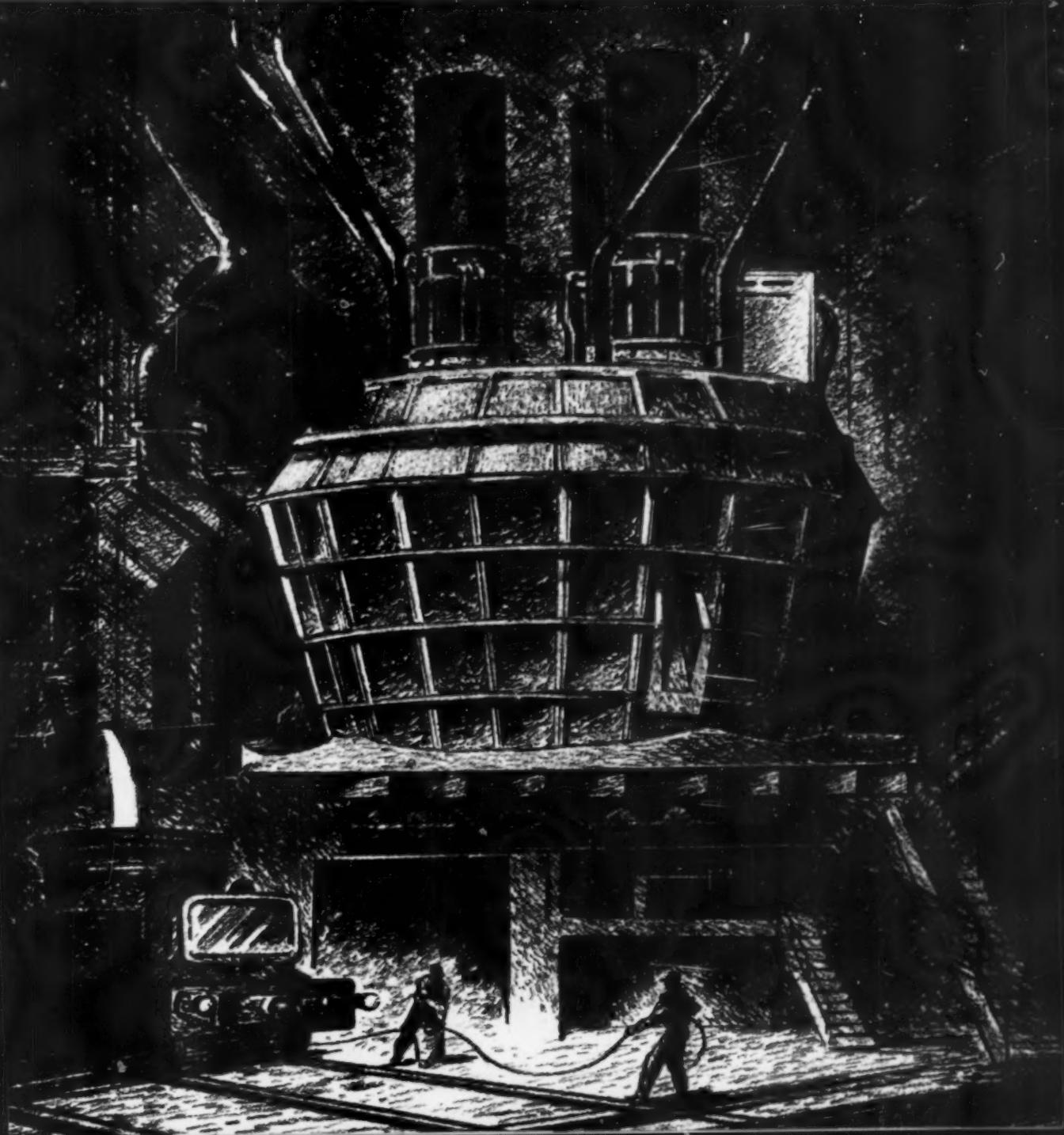
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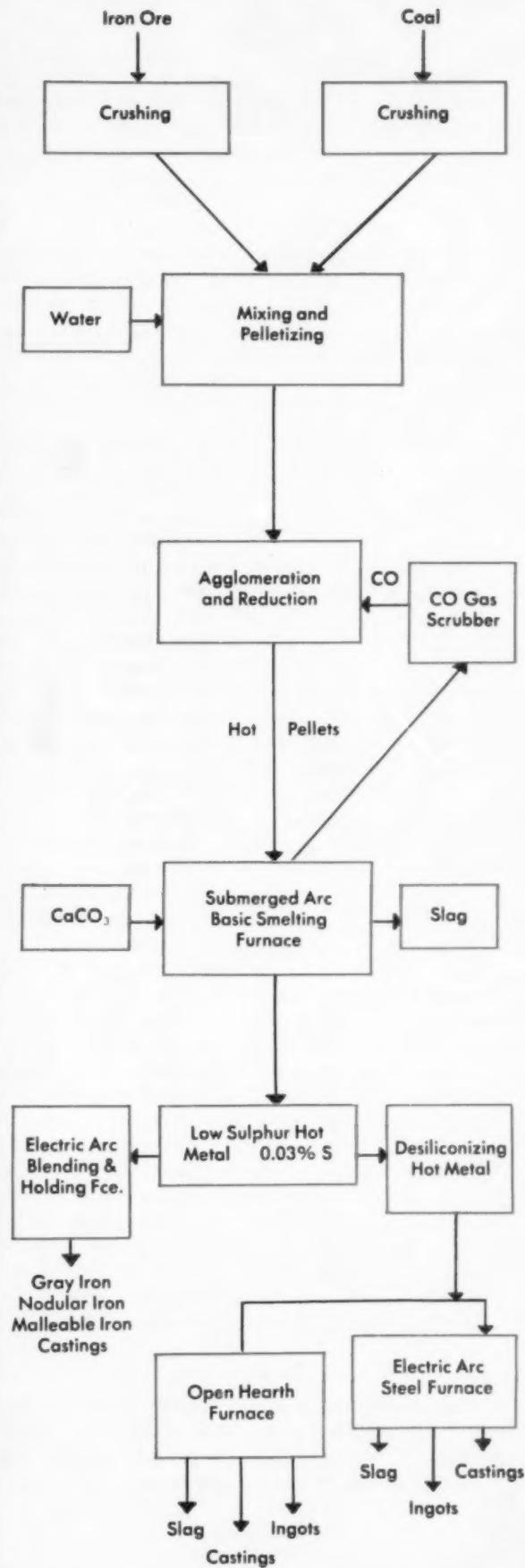
thus make possible production rates in electric steel furnaces of over 40 tons per hour in a 100 ton furnace instead of 20-25 tons per hour now made on cold scrap charges. This would reduce the cost of steel melting by saving power, electrodes, labor, etc. In addition, electric furnace pig iron can be produced and controlled within very close limits of carbon, silicon and sulphur, which should help to reduce processing costs where these elements must be controlled by present day operations. This over-all per ton saving might well be credited to the amortization of the hot metal producing unit.

The installation of an electric arc smelting plant using a pre-reduced iron ore charge should also be of great value to large iron and steel foundries which consume over 100 tons of cold pig iron per day. Such equipment could produce molten iron of low sulphur content economically, depending on the cost of iron ore at the plant. A large foundry today must pay \$60 per net ton for cold pig iron, plus freight and handling charges (\$5-\$12 per ton), plus about \$5 for melting. Therefore, molten iron ready for casting thus costs between \$70-\$75 per net ton. Hence an electric furnace pig iron installation would seem to be very attractive in many large foundries in view of the low cost of \$45.00 per ton or less. The low sulphur iron made in this basic furnace is also of great advantage for iron castings, particularly the new ductile cast iron.

An additional advantage of electric pig iron plants lies in the fact that they can be fairly small or relatively large . . . for example, the extreme versatility of this type of installation permits production of 200 to 400 tons per day from a single unit, and naturally much greater outputs from multi-units. As a matter of fact, a large multi-unit electric furnace plant can be built at a lower capital investment than a multi-unit blast furnace plant of similar capacity. Furthermore, such a multi-unit electric furnace plant will show operating costs comparable to a modern blast furnace plant.

#### Hydrogen Reduced Iron

Lately there has been considerable discussion of hydrogen reduced iron ore as a substitute for costly steel scrap. At the present time this operation is based on a fluo-solids reduction roast at various temperatures and pressures. Three pilot plants are using different methods of producing the iron; one operation uses pure hydrogen at 400 pounds pressure and conducts the reduction at about 900°F; the second method accomplishes the reduction at about 1300°F and 50 pounds pressure, also using pure hydrogen; and the third method is being studied at atmospheric pressure and the reduction is done at about 1600°F using a reducing gas consisting of carbon monoxide and hydrogen. In all of these schemes the finally



divided ore mineral is exposed to the reducing gas under the conditions listed with the aim of producing a high grade iron powder. The resulting powder is quite pyro-phoric and must be stored in steel containers until cold and then agglomerated or compacted in some manner which will enable it to be handled in melting. Little economic information is available on these tentative processes but one author has estimated that such material may be produced at a cost of \$45-\$50 per ton with natural gas as a source of hydrogen when the cost of the gas is less than \$0.50 per thousand cu. ft.

#### Sponge Iron

The Scandinavian steel producers have long used sponge iron as a source to substitute for steel scrap and some of the steel plants are producing steel wherein the sponge iron represents 50%-80% of the total metallic charge. It is reported that 130 thousand tons of this material per year are used for steel making in Sweden. Sponge iron is produced in crucibles, in tunnel kilns, and also in Wilberg-Sodarfers vertical furnaces at a cost estimated at \$45-\$55 per ton. The total iron content of such materials as H-iron and sponge iron is usually 90%-95%. When the cost of steel scrap exceeds \$50 a ton these materials which are charged cold into steel melting furnaces would be competitive with steel scrap.

The use of ordinary hot metal in electric arc furnaces has appealed to the electric furnace steel smelters for many years, but it has only occasionally been employed even in integrated steel plants because of the short supply of hot metal for the electric furnace. When hot metal is available in integrated steel plants, it has always been used in the open hearth rather than the electric furnace. Since normal hot metal contains about 4% carbon and 1%-1½% silicon, and since the electric furnace has a reducing atmosphere, much larger charges of iron ore are necessary to oxidize the impurities in hot metal charges. This gives rise to several difficulties such as large slag volume and a tremendous evolution of CO gas from the furnace, and it is probably for these reasons the use of normal hot metal is not employed in the arc furnace. The use of desiliconized hot metal overcomes these difficulties by reducing iron ore lime charges, slag volume, and greatly increasing melting time. If more hot metal could be made available, then it would naturally be used after desiliconizing in electric furnaces at great savings in cost.

#### Desiliconizing

Work during the past two years has clearly demonstrated that the use of ordinary hot metal can be affected by either blowing oxygen into the bath in the electric steelmaking furnace or treating the hot metal



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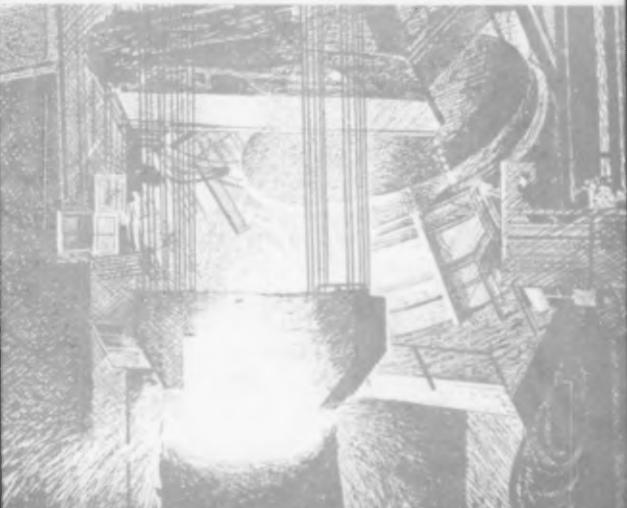
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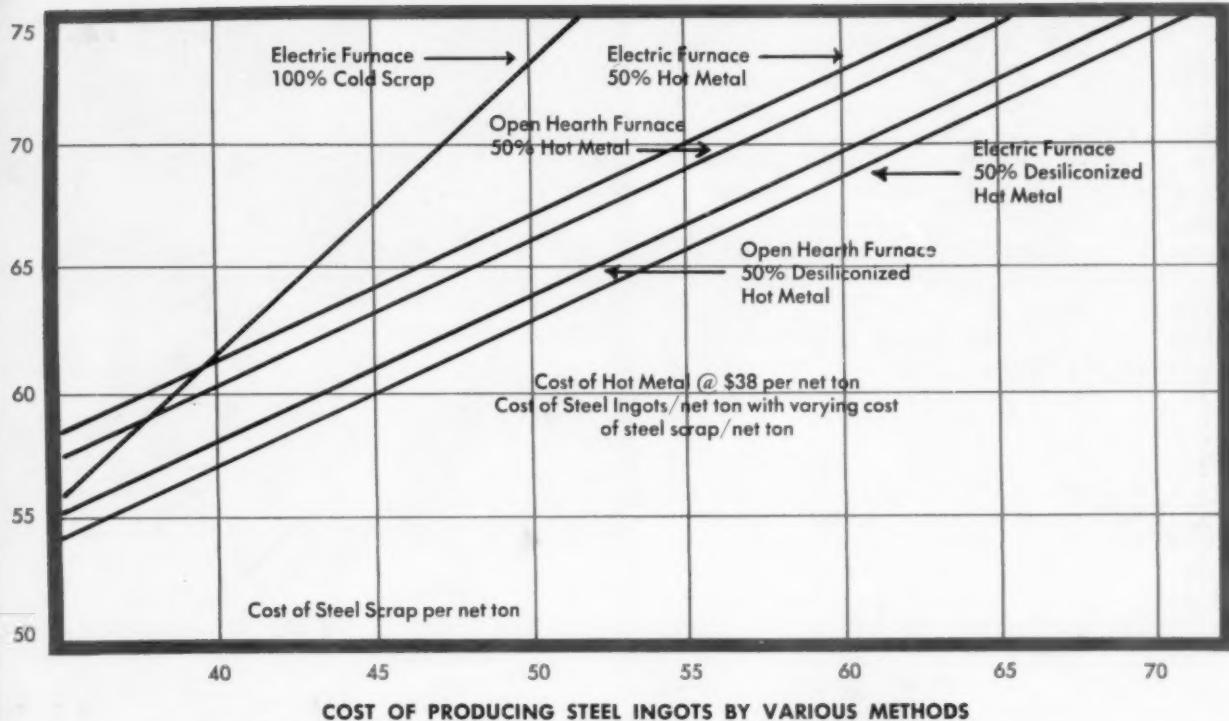
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with oxygen prior to charging into such a furnace. This operation is termed desiliconizing. The elimination of three-fourths of the carbon in hot metal and all of the silicon so greatly speeds up melting operations in the electric furnace that output is doubled, as the desiliconized hot metal represents a charge of molten steel scrap at a high temperature of about 3000°F. By use of such additions, the output of an electric arc furnace can be doubled by charges of 50%–60% desiliconized hot metal at a cost lower than the cost of melting a 100% cold scrap charge. Some furnaces in Germany are already operating with this practice, usually by blowing oxygen into the arc furnace, but good results have also been obtained on experimental heats where the desiliconizing has been accomplished prior to the charging.

#### Hot Metal Assures Flexibility

Based on the economic discussions in this article, the influence of widely varying cost of steel scrap on the cost of producing steel ingots by various methods has been calculated and is shown in chart above, which brings out the result. This comparison shows the relation of 100% cold scrap, 50% hot metal, and 50% desiliconized hot metal charges in both

open hearth and electric furnaces. In this chart the cost of pig iron is taken at \$38 per net ton.

It is thus obvious that an electric steel melting plant which has a source of molten hot metal at \$38–\$45 will assure a highly flexible situation which could be varied in relation to the widely different prices for cold scrap occurring from year to year.

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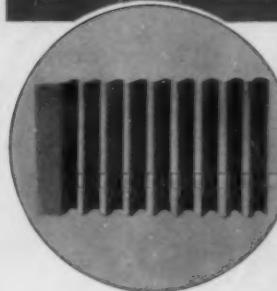
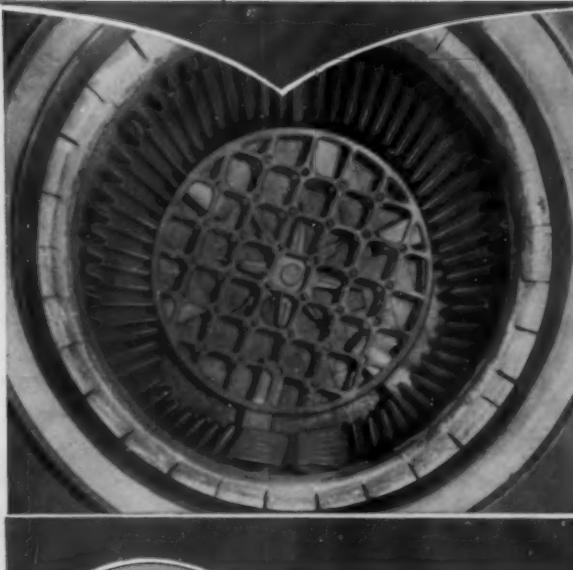
**IN CANADA:** National Carbon Company

Division of Union Carbide Canada Limited, Toronto.

**FROM THE OUTSIDE**

**... JUST ANOTHER  
LINDBERG PIT-TYPE  
CARBURIZING FURNACE**

**BUT LOOK INSIDE**



Note how CORRTHERM elements serve as baffles to direct forced convection streams through the charge.

CORRTHERM elements operate on extremely low voltage. No leakage through carbon saturation. Shock or short hazards eliminated. No complicated mountings required. An exclusive Lindberg development.



## **No Retort!**

Because it needs no retort, this new Lindberg electric vertical pit-type furnace gives you these important advantages:

- Lower initial cost, no retort to pay for.
- No expensive retort replacement.
- Downtime for retort replacement eliminated.
- Increased production because it heats faster.
- Exact atmosphere control maintains work quality.
- Versatile, carbon-diffusing and quenching along with carburizing. Adaptable to variety of work.

All this is made possible by Lindberg's new CORRTHERM electric heating element. For lower initial cost, lower maintenance costs, faster production, better quality control, why not look into this furnace. It's additional evidence that, if you're concerned with the application of heat to industry, better talk it over with Lindberg.

**LINDBERG**  
**ENGINEERING COMPANY**

2448 West Hubbard Street, Chicago 12, Illinois

Los Angeles Plant: 11937 S. Regentview Ave., at Downey, Calif.  
Toronto Plant: EFCO-Lindberg, Ltd., 11 Front Street, East

# drive gears in BOLENS TRACTORS toughness of MUELLER BRASS "600" series bronze alloys

Forged bronze gears made from tough, long-wearing Mueller Brass Co. "600" bearing alloy are proving their ability to withstand punishment in the popular outdoor power equipment manufactured by the Bolens Products Division of Food Machinery and Chemical Corporation, Port Washington, Wisconsin. The Junior and Super Mustang rotary tillers, all employ "600" main drive gears to dependably transmit engine power to drive assemblies. The going is rough for equipment of this type in cultivating or tilling heavy soil—but Bolens has a record for ruggedness and, on these and many other Bolens products as well, Mueller Brass Co. "600" gears help make possible that fine performance.

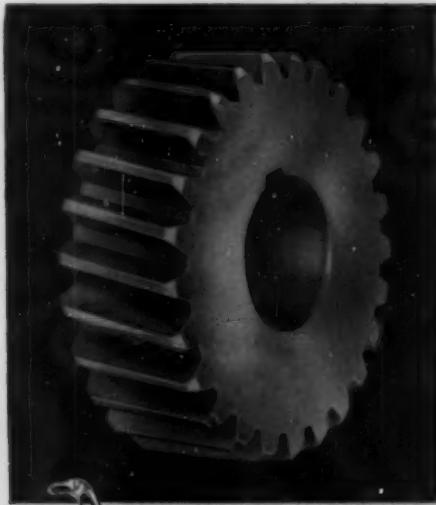
Mueller Brass Co. "600" bearing bronzes are available as forgings, or in rod form. They provide unusually high tensile strength, a dense structure, good resistance to corrosion, and excellent bearing properties. Because of their good machining qualities, the "600" series bronzes can be finished readily—usually at substantial savings in COST.

It will pay you to investigate these alloys for your products . . . why not write today for full information.

Bolens' Ridemaster riding model garden tractor incorporating an 8½" diameter "600" bronze gear.



# and TILLERS prove CO.



Bolens' Super Mustang  
rotary tiller incorporating  
a 25-tooth "600" series  
bronze worm gear.

• WRITE TODAY FOR THE  
ENGINEERING MANUAL YOU NEED

Mueller Brass Co. Forgings   
Engineering Manual H-58565

Tuf Stuf Aluminum Bronze Alloys   
Engineering Manual H-58563

"600" Series Bearing Alloys   
Engineering Manual FM-3000

Copper Base Alloys in Rod Form   
Engineering Manual FM-3010



## METALS AND ALLOYS REVIEW



by FRANK M. LEVY

Vice-President and Director of Research

One of the most interesting things about our 600 series bearing alloys is the great variety of products in which they find application. In the advertisement to the left you can see how the Bolens people put 600 gears to work in their rotary tillers and garden tractors. Those gears are big, take a lot of abuse, and meet the job needs perfectly. We also make a lot of small parts, too, that have been specified because of the many unusual properties of this series of alloys.

One good example that comes to mind is a shaft bushing on a rotary selector switch that we make for an instrument manufacturer. This selector is used for switching sound-powered telephone circuits aboard Naval vessels. One of the most important considerations in the choice of 600 alloy for this bushing was its resistance to abrasive action on and against a rubber "O" ring. The acceptance test required a stainless steel shaft riding in the bushing to rotate "dry" for a minimum of 50,000 cycles consisting of 360° rotation clockwise followed by a 360° rotation counter-clockwise. The "O" ring must still form a watertight seal at the end of the test. Our 602 alloy was the only one of several materials tested that met the specs. That was pretty good evidence in itself of resistance to abrasion, but, in addition, this customer also found that the use of 602 eliminated the headaches they previously had with seizing and galling.

The pounding action caused by the indexing mechanism attached to the shaft used to give them no end of seizing troubles. The chief product engineer is extremely happy about the way our alloy is performing. Mention was also made of the fact that the corrosion resistance of 602 was mighty impressive. In this application, the alloy passed the 200-hour Navy salt spray test with flying colors.

So, big or small, it seems that there is no end of applications for 600 series alloys. We even have parts working in a machine that slices frankfurters as well as gears in fishing reels. So, it seems that 600 runs the gamut from "red hots to reels". Well, it looks like the end of the page is here again, so I'll close for now. However, if you have any problems or questions about non-ferrous alloys or you're having trouble getting desired performance from a part, why not drop me a line here in Port Huron, and possibly I can be of some service. Send a part print along if you like, and we'll be glad to make proper recommendations.

Thanks again for your time.

198



# MUELLER BRASS CO.

P O R T H U R O N ' 2 8 , M I C H I G A N

For whatever you fabricate . . .

# **N-A-X FINEGRAIN STEEL COMBINES STRENGTH WITH FORMABILITY**

Among the many economical advantages of N-A-X FINEGRAIN—a low-alloy, high-strength steel with widely diversified applications in modern metals design—is its combination of great strength with excellent formability. Even at the higher strength levels (50% greater than mild carbon steel) N-A-X FINEGRAIN can be cold formed and drawn into difficult stampings and cold formed shapes.

Take these qualities and add the ability of N-A-X FINEGRAIN to be readily polished to a high luster at minimum cost, and when plated, you have a steel ideally suited for such applications as bumpers, bumper guards, and many others where strength and toughness with good finish is important.

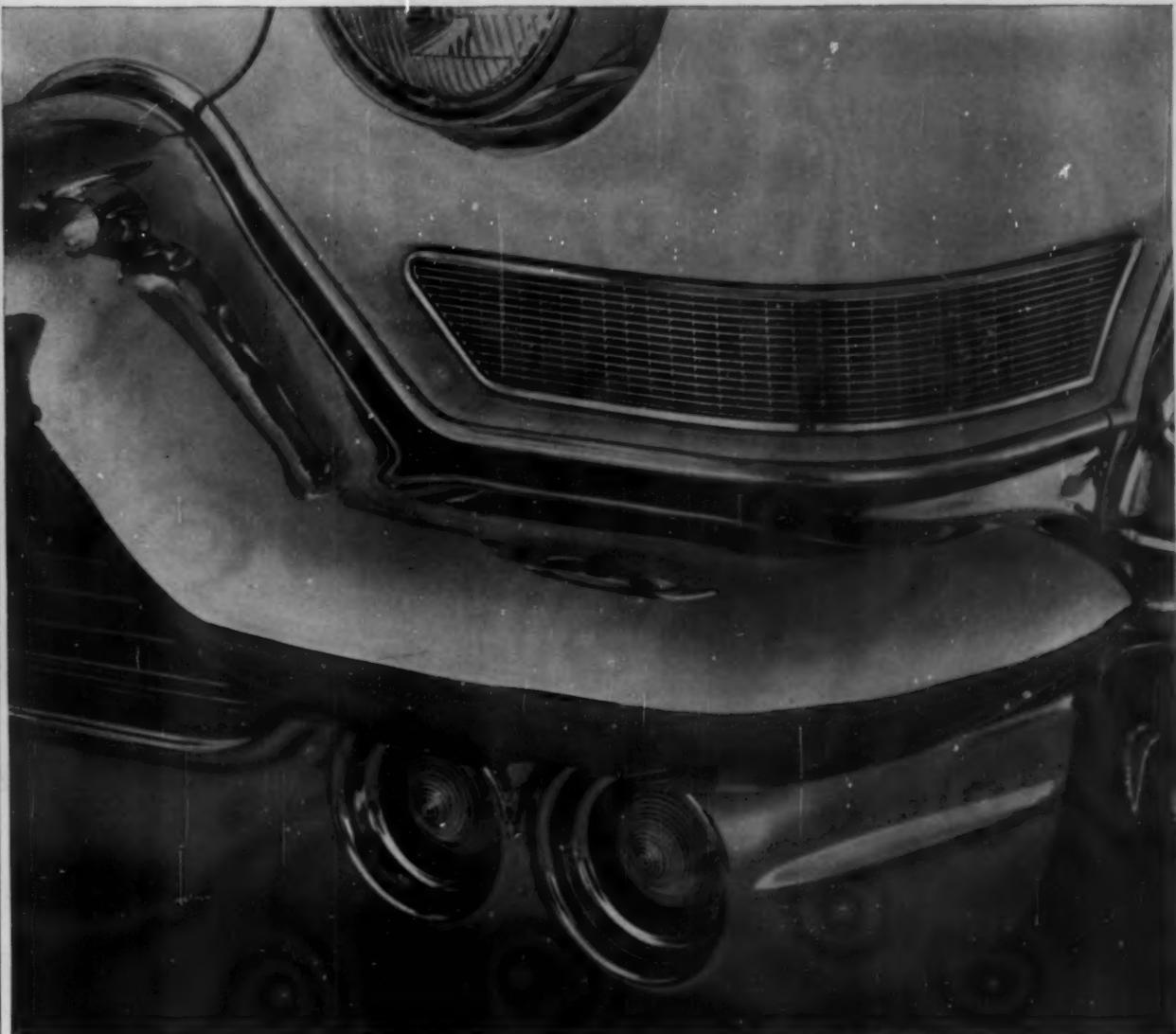
Engineers and designers like N-A-X FINE-

GRAIN especially because its physical properties are inherent in the "as rolled" condition. No subsequent treatment is needed to insure its characteristics.

Check these other important advantages: N-A-X FINEGRAIN steel, compared with carbon steel, is 50% stronger • has high fatigue life with great toughness • is stable against aging • has greater resistance to wear and abrasion • is readily welded by any process • offers greater paint adhesion. NOTE: Where greater resistance to atmospheric corrosion is an important factor, our N-A-X HIGH-TENSILE steel is recommended.

For whatever you fabricate, from bumpers to bulldozers, with N-A-X HIGH-STRENGTH steels you can design longer life, or less weight, and economy into your products. Let us show you how.





*One of many applications where N-A-X FINEGRAIN'S strength with formability saves production money.*



N-A-X Alloy Division, Dept. E-4

**GREAT LAKES STEEL CORPORATION**

Detroit 29, Michigan

Division of

**NATIONAL STEEL CORPORATION**



**N-A-X Alloy Div., Dept. E-4**

**Great Lakes Steel Corp., Detroit 29, Mich.**

- Please send me technical data on N-A-X FINEGRAIN steel.
- Please have your representative contact me.

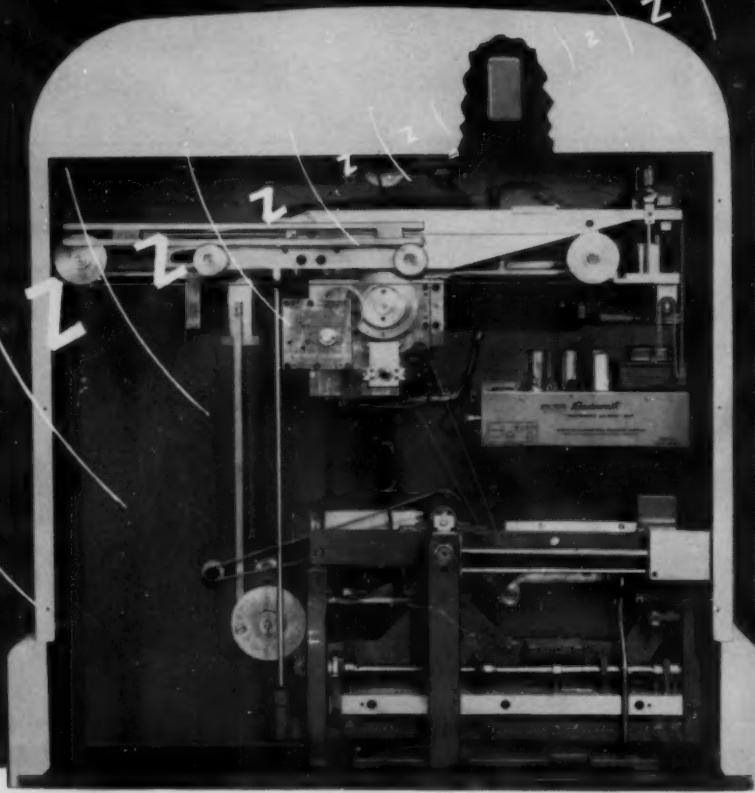
Name \_\_\_\_\_ Title \_\_\_\_\_

Company \_\_\_\_\_

Street \_\_\_\_\_

City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_

This safety signal is saying:



"reduce  
load rate  
application!"

A test reading taken now would probably be erroneously low — or the machine might be running dangerously overloaded.

That's why Riehle's Electro-Balanced indicating unit always *buzzes a warning when a load is being generated on the specimen at a higher rate than a servo system can follow.*

This buzz tells the operator to reduce the load rate application. It prevents wrong readings or possible machine damage. This safest and most sensitive of all indicating units is offered for both hydraulic and screw power testing machines — by Riehle. It's a Riehle feature that gives users confidence in their test results.



NEW BULLETIN . . . MAIL COUPON

RIEHL TESTING MACHINES

Division of American Machine and Metals, Inc.  
Dept. MP-757, East Moline, Illinois

Please send your free 4-page Bulletin RU-14-56 with full data on the new Riehle Electro-Balanced Indicating Unit.

COMPANY \_\_\_\_\_

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CITY \_\_\_\_\_ ZONE \_\_\_\_\_ STATE \_\_\_\_\_

ATTENTION MR. \_\_\_\_\_

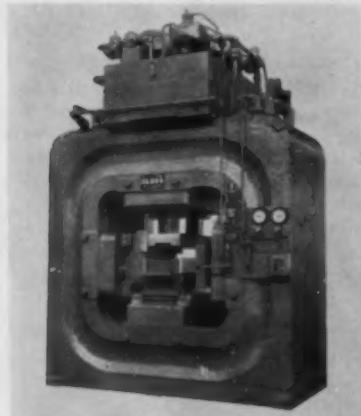
**Riehle** TESTING MACHINES  
A DIVISION OF  
American Machine and Metals, Inc.  
EAST MOLINE, ILLINOIS

## APPLICATION and EQUIPMENT

# new products

### Powdered Metal Forming

A new angle-type powdered metal forming press has been announced by Elmes Engineering Div. of American Steel Foundries. Capacity of the main ram is 1000 tons, of the side ram 750 tons. Independent hand lever control is provided for each ram, with a



mechanical interlock preventing movement of main ram until a predetermined tonnage is reached on the side ram. Remote control valves, manually operated, permit variation of tonnage applied to either ram. Die area is faced with hardened steel wear plates which are reversible. The working area is accessible from either the front or rear of the press.

For further information circle No. 1 on literature request card, page 48-B.

### Soldering

Two new high temperature soldering materials, solder No. 805 and soldering flux No. 66, have been announced by the Aluminum Co. of America. A high-zinc solder (95% zinc, 5% aluminum), it will join all aluminum alloys and make joints between aluminum and other metals such as copper, brass, steel, stainless steel and nickel. With melting range of 715 to 725° F., the new solder can be heated by any of the conventional methods. It works most effectively when preplaced in or near a joint, rather than being manually fed. The

soldering flux No. 66, recommended for use with the new solder, can be applied dry, or as a 70% flux-30% normal propyl alcohol solution. It reacts at 720° F. to wet aluminum with zinc, and there are no restrictions regarding the method of heating.

For further information circle No. 2 on literature request card, page 48-B.

### Bright Gold Plate

A hard bright gold finish with hardness of 130 to 150 DPH and low stress with less porosity than the usual bright gold has been announced by Technic, Inc. Karat is high, in the 23-plus range. A plating range from 60 to 95° F. means no cooling or heating is required. Cyanide is less than 1/10 oz. to the gallon. No organic brighteners are required.

For further information circle No. 3 on literature request card, page 48-B.

### Fluidity Tester

A new technique for measuring the fluidity of molten metals has been announced by the Harry W. Dietert Co. The Rugone tester measures



fluidity by using a controlled partial vacuum to pull a sample of metal into a preformed, precision pyrex tube. The tester is portable.

For further information circle No. 4 on literature request card, page 48-B.

### Gas Analysis

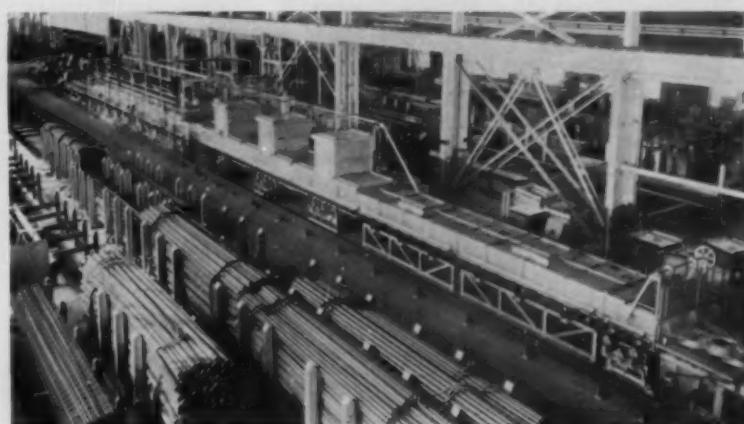
A new vapor phase for gas chromatography has been announced by Central Scientific Co. The vapor phase analyzer is housed in a standard cylindrical oven, which can maintain constant temperatures, thermostatically regulated to  $\pm 0.5^\circ$  C., from room temperature to 210° C. Helium, nitrogen, hydrogen, dried air and a variety of other carrier gases may be

### Annealing Furnace

A 200-ft. long final annealing furnace employed in copper tubing production has been announced by Surface Combustion Corp. It has a capacity of 12,000 lb. per hr. heated to

1400° F. Furnace accommodates coiled stock and tube lengths up to 20 ft. Heating cycle varies from 40 to 50 min.

For further information circle No. 5 on literature request card, page 48-B.

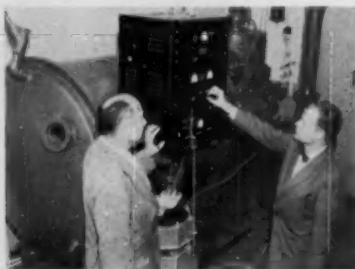


used. The detector is a Gow-Mac diffusion type thermal conductivity cell with a time constant of less than 1 sec. and negligible drift. Dimensions of the unit are 18% in. wide by 15 in. deep by 27½ in. high (less thermometer and flow meter). Weight is 58 lb. and the power requirement is 500 watts at 110 volts a.c.

For further information circle No. 6 on literature request card, page 48-B.

### Vacuum Cadmium Plating

Lockheed Aircraft Corp. and Ana-dite, Inc., have announced a method of vacuum deposition of cadmium on



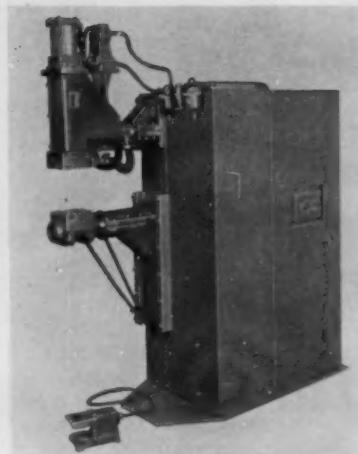
steel parts so that hydrogen embrittlement has been eliminated. Deposits of 0.0003 to 0.0005 in. can be uniformly maintained and deposits greater than this can be accomplished if desired. The throwing power of the vacuum

process exceeds that of conventional plating and an almost completely uniform coating is obtained in both high and low areas or in recessed places. The parts are suspended in a vacuum chamber and the cadmium is vaporized beneath them. No current is at any time passed through the parts, and they remain at room temperature throughout the process.

For further information circle No. 7 on literature request card, page 48-B.

### Welder

A new roller head press-type combination spot and projection welder has been announced by Allied Welder Corp. The new welder takes up approximately 1 ft. less in width than conventional welders. This is due to the placing of the arms off center (either to the right or left) with the controls installed next to the arms and within the welded chassis frame where they are protected. Two machines may be placed so arms are within 9½ in. for sequence welding operations. Design permits extension of the arms by loosening three screws on each arm casting to give up to 30 in. throat depth. Vertical adjustment of the lower arm up to 15 in. is provided. Welders are available in two standard sizes: 30, 50 and 75 kva. with 1000 psi. at 80 lb. line pressure



and 75, 100 and 150 kva. with 2300 psi. at 80 lb. line pressure.

For further information circle No. 8 on literature request card, page 48-B.

### Stretching Aluminum

A stretcher able to stretch an aluminum plate up to 6 in. thick, 90 ft. long and 12 ft. wide is in operation at the Reynolds Metals plant at McCook, Ill. The machine can exert a pulling force of 16,000,000 lb. in stretching aluminum to release inter-



nal stresses set up in rolling and heat treating processes. Plates stretched are used to form large wing structures for airplanes. The machine weighs over 4,400,000 lb. is 182½ ft. long, 29 ft. wide, 21½ ft. high from the base. Two thirds of its mass is below the floor line.

For further information circle No. 9 on literature request card, page 48-B.

### Brazing Alloys

Special vacuum-tube grade silver and gold brazing alloys have been announced by Handy and Harman. These alloys are designed specifically for brazing electronic components in which the concentrations of metallic impurities must be kept at a minimum. These two silver and five gold alloys are carbon-free and meet all applicable industry specifications on maximum content of cadmium, zinc and other volatile elements not allowable for vacuum-tube work. They are

## HARDNESS CONVERSION CHART For Every Shop That Does Hardness Testing

This latest and most nearly accurate Hardness Conversion Chart is a necessity wherever hardness testing is done. It has been compiled and produced by CLARK, makers of the internationally repected CLARK Hardness Tester for "Rockwell Testing." Printed on heavy stock convenient for wall mounting, the chart is offered free of charge to hardness tester users. Just attach this ad to your letterhead or write "Send wall chart." A copy will be mailed to you without charge or obligation.

P.S. If you would also like information on CLARK Standard and Superficial Hardness Testers, we'll be glad to send that along too.



# CLARK

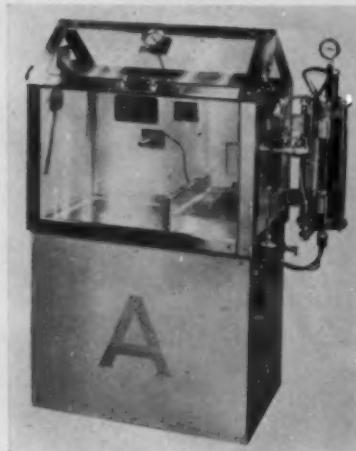
CLARK  
INSTRUMENT  
INC.  
10202 Ford Road  
Dearborn, Mich.  
U.S.A.

supplied in wire, strip and sheet form in all the usual gages.

For further information circle No. 10 on literature request card, page 48-B.

### Salt Spray Testing

A new, all-Lucite salt spray test chamber for determining salt fog corrosion resistance of materials and components has been announced by Associated Testing Laboratories. The chamber, when connected to a low pressure air supply, produces a fine mist, and reaches test conditions within 15 min. Specimens to be tested are



then suspended from Lucite hanger rods which are supplied with the chamber. Bulkier components can be placed on the bottom of the chamber supported by Lucite rods to avoid contact with the salt solution. The chamber is equipped with temperature controllers and indicators for both the chamber and the air saturation tower. Dimensions of the chamber are 20 by 20 by 20 in.

For further information circle No. 11 on literature request card, page 48-B.

### Blast Cleaning

A new automatic blasting machine designed to handle organic abrasives such as walnut shells, pecan shells, rice hulls, which clean and deburr without stock removal or discolora-



tion of the work, has been announced by Cro-Plate Co. Parts are manually loaded at the left. In sequence they are indexed through a compressed air blow-off cabinet for removal of moisture; the blast cabinet where the

work holding fixtures are rotated under the blast guns; a secondary blow-off cabinet where any residual abrasive grain is removed, then to a selective unloading device which loads the parts alternatively to the left and right.

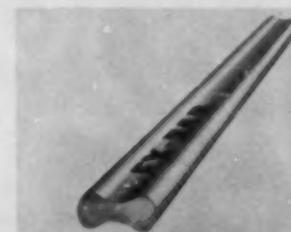
For further information circle No. 12 on literature request card, page 48-B.

### Optical Strain Gage

A new optical strain gage capable of measuring strain characteristics of materials subjected to temperatures up to 1000° F. has been announced by the American Instrument Co. It is designed for measurement of tension and compression strains as small as 0.000004 in. and in a variety of materials and parts. The strain gage consists of two essential parts—the auto-collimator and the extensometer (or gage). The strain being measured is manifested by a rocking of a mirror within the extensometer. The degree of rocking is then measured by the auto-collimator. Any number of extensometers can be used with a single auto-collimator, and either flat or cylindrical specimens may be tested. For further information circle No. 13 on literature request card, page 48-B.

### Deoxidizing Steel

A new type aluminum bar for deoxidizing steel in the ingot mold has been announced by Cleveland Electro Metals Co. The new product has a



special design and method of use that dissolves and diffuses the aluminum uniformly. Ex-Bars are made in three sizes and in any length.

For further information circle No. 14 on literature request card, page 48-B.

### Tube Stacking

A new, automatic stacker designed to handle either tubes or bars from a cut-off machine and stack them in a storage rack has been announced by Spurgeon Co. The electric control panel houses the transformer, switches, relays and wiring necessary to operate the stacker. As the tube (or bar) is released by the cut-off machine, the angle slides at the front of the machine direct the tube to the bottom of the slide. Next, a pair of steel blades lifts the tube up above a pair of dogs

**from cold strip  
to finished tubing  
IN SECONDS!**



**with a  
YODER  
ELECTRIC-WELD  
TUBE MILL**

One of the fastest . . . and one of the least expensive . . . methods of making steel tubing is with a Yoder Electric-Weld Tube Mill. The Yoder method eliminates the need for time-consuming heat treatments and costly conditioning furnaces for most tube needs. Scrap losses, too, are far lower than any other method . . . usually less than 2%.

The Yoder Type-M Mill shown above is operated by one man and a helper. Coiled strip on this mill is continuously cold-rolled, welded and cut to required lengths in a matter of seconds . . . at speeds up to 340 f.p.m. The quality of the resulting tube is *constantly* better than the requirements of commercial standards. This is one of many reasons why manufacturers and users of tubing the world over are using more Yoder mills than all other makes combined.

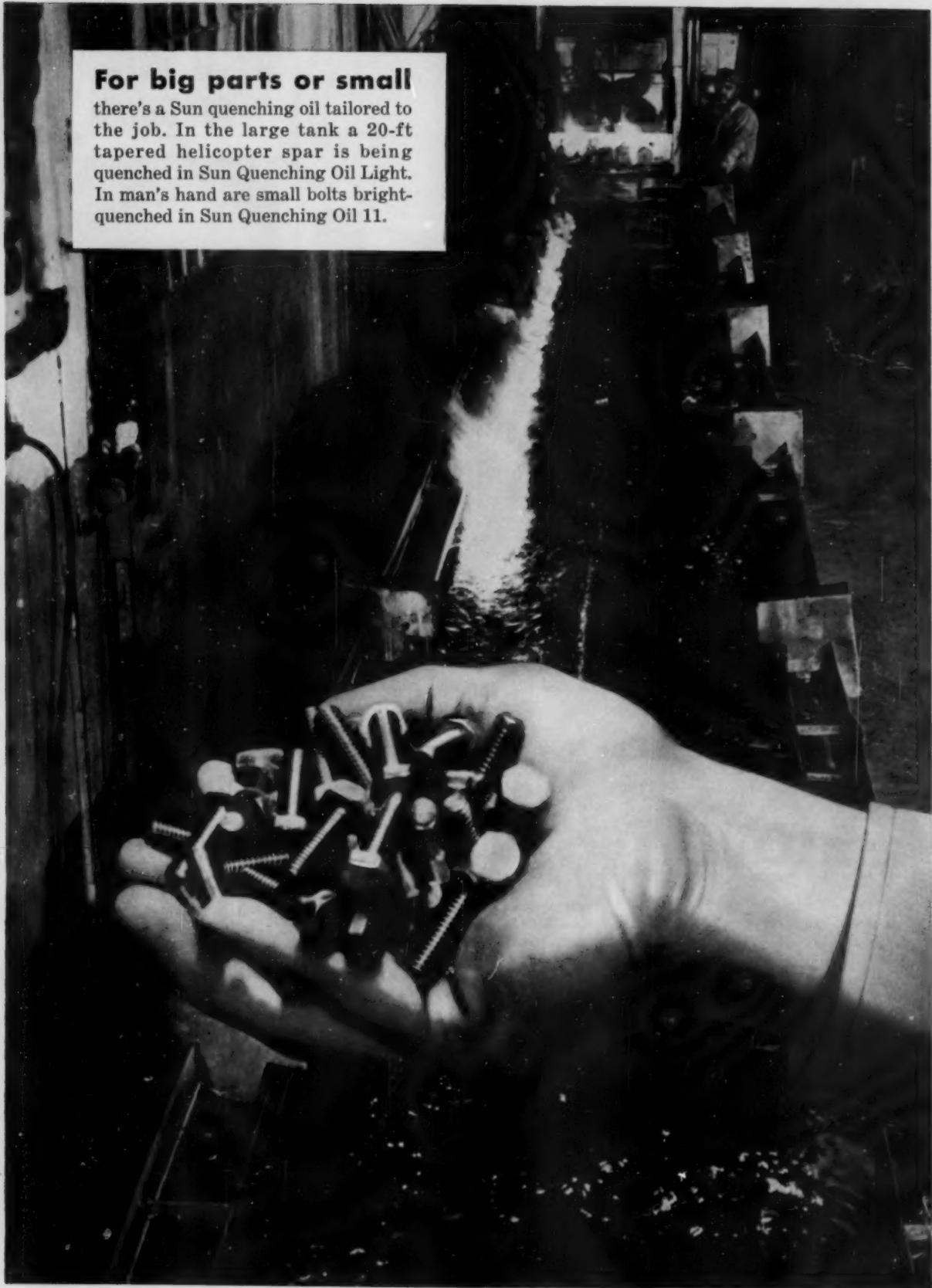
If your business requires pipe and tubing, ferrous or non-ferrous, in sizes from  $\frac{1}{4}$ -inch up to 26-inch diameter, Yoder can supply the engineering service and machines to produce it faster and better for less! For complete details, write for the Yoder Tube Mill Manual. It's yours for the asking.

**THE YODER COMPANY**  
5595 Walworth Ave. • Cleveland 2, Ohio



## For big parts or small

there's a Sun quenching oil tailored to the job. In the large tank a 20-ft tapered helicopter spar is being quenched in Sun Quenching Oil Light. In man's hand are small bolts bright-quenched in Sun Quenching Oil 11.



# SUN QUENCHING OILS CAN SOLVE ALL OF YOUR OIL-QUENCH PROBLEMS

**SUN QUENCHING OIL LIGHT** keeps coolers cleaner longer because it has a natural detergency that cuts down sludge formations. By using Sun Quenching Oil Light many people have cut cooler maintenance costs by as much as 75 to 80 per cent. And they're getting low drag-out and uniform quenching.

**SUN QUENCHING OIL 11** has a high flash point. Moreover, it resists breakdown at high temperatures. These characteristics make it ideal for bright quenching and for use in systems operating at above-normal temperatures.

**SUNQUENCH 78** is a high-speed quenching oil. You can use it whenever the nature of the steel, the size and shape of the parts, or other conditions make it difficult to get satisfactory results with conventional quenching oils. By using Sunquench 78, steels of lower hardenability may often be used to replace more expensive steels.

**IN ADDITION** to these three quenching oils, Sun makes several others for special applications. No matter what your quenching problem, there's a Sun quenching oil to solve it.

#### READ THESE TECHNICAL BULLETINS

Free technical bulletins are available to give you full details of Sun's outstanding quenching oils. Call your Sun representative or write for **Sun Quenching Oil 11** (Bulletin 29), **Sun Quenching Oil Light** (Bulletin 37), **Sunquench 78** (Bulletin 45).

Write to **SUN OIL COMPANY**,  
Philadelphia 3, Pa., Dept. MP-7



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#### INDUSTRIAL PRODUCTS DEPARTMENT

**SUN OIL COMPANY** **PHILADELPHIA 3, PA.**

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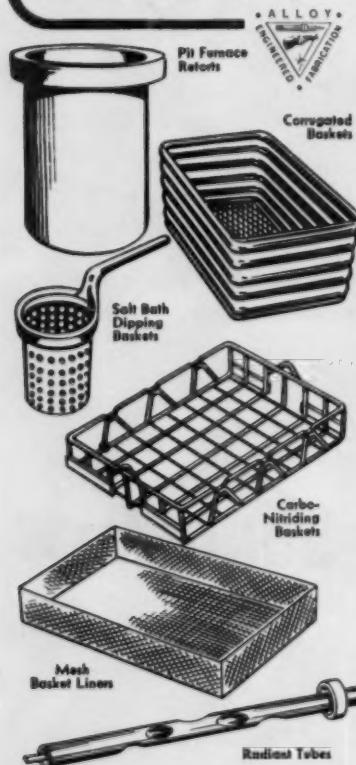
## NOW Available . . .

### MISCO Heat-Treating Tools from Stock!

MISCO heat-treat process equipment is engineered and fabricated by qualified specialists in the field of heat-resisting alloy materials.

With a wide variety of job-proven heat-resisting steel products available for immediate delivery, Misco Fabricators provide a real service to heat-treaters, who no longer need carry an expensive inventory of equipment.

Remember, whatever your need, Misco Fabricators offer sound, economical designs in the best metal for your purpose. It pays to do business with Misco Fabricators—Specialists in Nickel-Bearing Alloy Fabrication.



Special Equipment Designed and Made to Order

#### MISCO FABRICATORS, INC.

Designers, Builders, Fabricators of Heat-Resisting Alloy and Stainless Steel Equipment  
2420 WILLS AVENUE • MARYSVILLE, MICHIGAN  
TELEPHONE YUKON 5-6191

into the curved section of the machine, pushing the previously handled tubes up the inclined section to form a magazine fill. Then the entire layer of tubes is pushed up the curved section to the top of the machine. The



layer is lifted by a grab and transferred to the storage rack on the lift table. The lift table is lowered a distance equivalent to the diameter of the tubes so that it is ready for the next load.

For further information circle No. 15 on literature request card, page 48-B.

#### Thickness Measurements

A new quality control instrument for measuring as little as 0.0001 in. of paint film, electroplating or metal overlay has been announced by General Motors Research Staff. The new device, the Laminagage, is a non-destructive tester that can be used for a high rate of production testing. It



is portable and can be plugged into any 110-volt outlet in a plant. The instrument consists of a small metal cabinet containing electronic equipment and a probing coil connected by coaxial cable with the cabinet. The probing coil is used to contact the part under test; it can be designed for probing parts of virtually any shape. When the probing coil contacts the part under test, the thickness of the paint film or plating overlay on the part registers on the dial on the front of the cabinet.

For further information circle No. 16 on literature request card, page 48-B.

#### Gas Converter

Hevi-Duty Electric Co. has announced a new automatic gas converter. This unit produces a prepared

atmosphere through the exothermic reactions of controlled ratios of gas and air. Manufactured, natural or bottled gas may be used and no outside source of air is required. The unit is equipped with an automatic ignition. Gages, flow meters and sampling valve are all panel mounted.

For further information circle No. 17 on literature request card, page 48-B.

#### Induction Heaters

Magnethermic Corp. has announced a new line of electronic induction heaters, available in three ratings of 15, 30 and 40 kw. Each heater can be tailored or custom designed to a specific heating application. New electronic induction heaters are available with built-in high frequency output



transformer, stepless power control, J.I.C. electrical specifications, dust-proof cabinet, built-in heat exchanger and pump, constant voltage filament supply, power tap switch, ceramic water columns, electronic keying and power tap switch. All heaters have a full complement of instruments.

For further information circle No. 18 on literature request card, page 48-B.

#### Powdered Metal Press

Lake Erie Machinery Corp. has announced an angle-molding type hydraulic press of 1000 tons main ram pressure and a side ram of 500 tons.



Designed for making 2½ by 2½ by 14 in. zirconium briquettes, the press can be used for rectangular or square section shapes also. The 500-ton horizontal die sealing ram permits the use of split dies. The bed is also provided with an opening through which material may be extruded. Use of the front and back plate design furnishes the required rigidity. Vertical daylight is 22 in. with an 8-in. shut height. Horizontal daylight is 28 in. combined with a 6-in. ram stroke. Vertical platen is 30 by 34 in.

For further information circle No. 19 on literature request card, page 48-B.

### Cleaning Machine

A new automatic cleaning, phosphate coating and drying machine designed to handle a variety of metal



stampings has been announced by Alvey-Ferguson Co. The machine incorporates an overhead conveyor and

a flat wire-mesh belt conveyor to carry stamped parts through the automatically-timed cycles. The two conveyors pass through a single tunnel and use common solution tanks and spray system and common headers for water and drains. Leakage and wet floors are eliminated by the use of a new type vertical immersion pump. Individual pressure-type gas burners are used to maintain proper temperatures in each solution tank.

For further information circle No. 20 on literature request card, page 48-B.

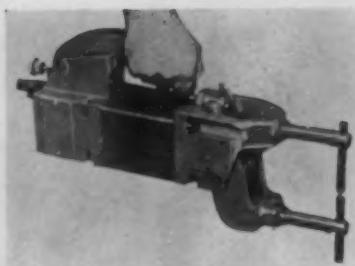
### Mold Plug

A new large size has been added to its regularly stocked line of carbon mold plugs by National Carbon Co. Measuring 6 15/16 in. in large diameter, 6 1/16 in. in small diameter and 5 in. in length, the new plug weighs approximately 9.7 lb. Carbon mold plugs resist thermal shock and hot-metal erosion, do not contaminate nor stick to the ingot and can be used more than once.

For further information circle No. 21 on literature request card, page 48-B.

### Spot Welder

A new spot welder has been announced by Aro Spot Welders Div. of Guthery Machine Tool Corp. It has



high welding current for its size. One-hand operation reduces operator fatigue. It has a built-in trip switch. For further information circle No. 22 on literature request card, page 48-B.

### Barrel Plating

A new automatic barrel plating machine that offers variable cylinder rotation speeds and a centralized cycle control has been announced by Hanson-Van Winkle-Munning Co. With a return-type conveyor, the machine permits a continuous flow of small parts and hardware from the production department or loading dock through the machine and back without manual handling. The Mercil-type barrels are driven by a constant-tension v-belt and pulley arrangement that permits changing speed of cylinder

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**HANDLE  
EXTRA-TOUGH  
THERMOCOUPLE  
WIRE JOBS WITH  
T-E "Ceramo"**

"Ceramo" does the jobs too tough for ordinary thermocouple wire. "Ceramo" construction—thermocouple elements and inert metallic oxide insulation encased in a seamless metal sheath—has resulted in a wire of unusual durability.

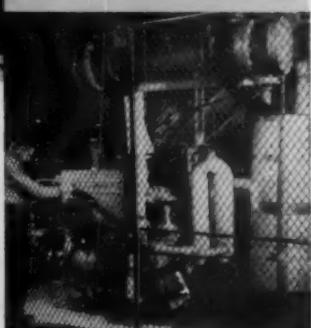
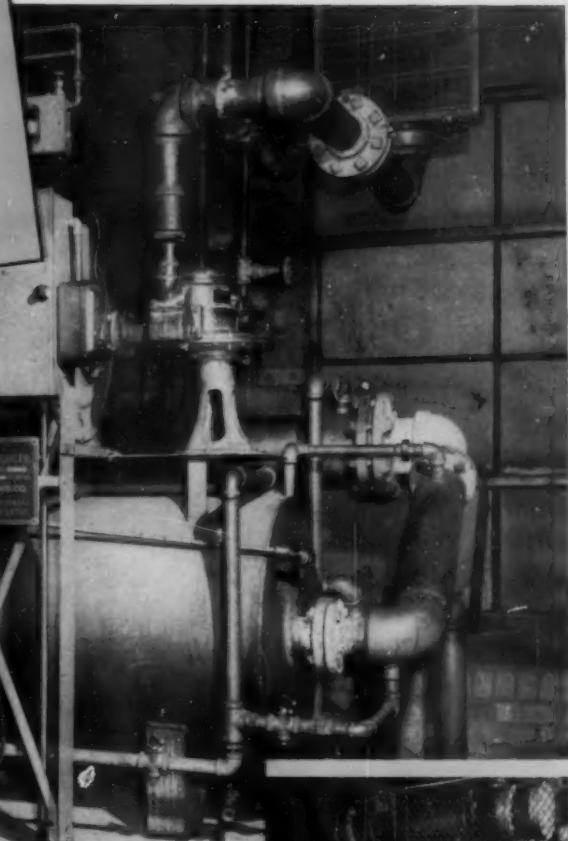
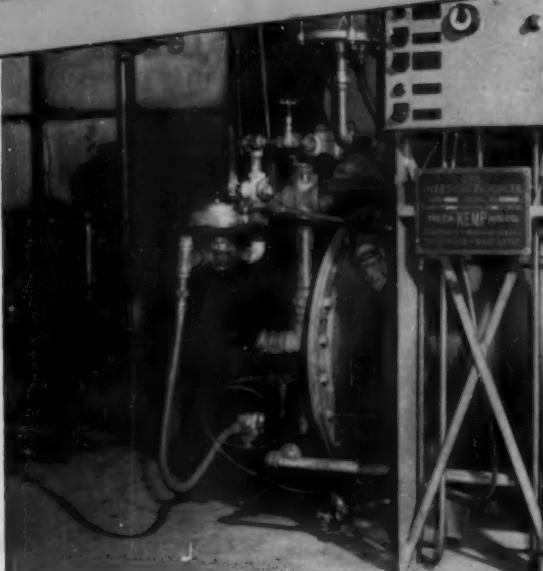
Basically rigid, "Ceramo" can be bent on an extremely small radius without shorting or grounding. Enclosed "Ceramo" thermocouples last longer and respond faster than conventional types. Available in all standard calibrations. Depending on conductors and sheath material, "Ceramo" can be used up to 3000°F. Sheath for T/C wires—Stainless Steels, Inconel, tantalum and platinum. For T/C extensions—copper-nickel alloy, plain or galvanized cold-drawn steel.

WRITE FOR  
BULLETIN 31-300-H.

**Thermo Electric Co., Inc.**  
SADDLE BROOK, NEW JERSEY  
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

Case No. 61

Kemp Inert Gas  
Generators more  
dependable at  
Belden Mfg. Co.



## How Belden utilizes two Kemp Generators in annealing copper wire

Annealing copper wire necessitates cooling in an oxygen-free atmosphere to prevent harmful oxidation. For the required protective atmosphere in this process, the Belden Mfg. Co., Chicago, Ill., generates its own inert gas. But the generating equipment formerly used by Belden did not operate reliably . . . results were erratic. So Belden installed two Model MIHE Kemp Inert Gas Generators to handle this important job.

### And Kemp Handles the Job

These two Kemp units assure Belden of a *dependable* inert supply. They deliver a more constant flow at the rated pressure . . . have been operating smoothly and

satisfactorily since installation. Kemp's ability to produce a chemically clean inert at a *specific analysis regardless of demand* eliminates the danger of fluctuation at a critical stage.

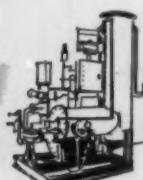
### Kemp Units Engineered for Service

Like Belden, you specify reliability when you specify Kemp. Every Kemp design includes the Kemp Industrial Carburetor for complete combustion without tinkering, without waste . . . for simplified installation and maintenance. Every Kemp design includes the very latest fire checks and safety devices. Annealing, hardening, sintering—whatever your problem, find out today how Kemp engineers can help you.

Generator on first floor of  
plant is enclosed in wire  
cage to prevent tampering  
with controls.

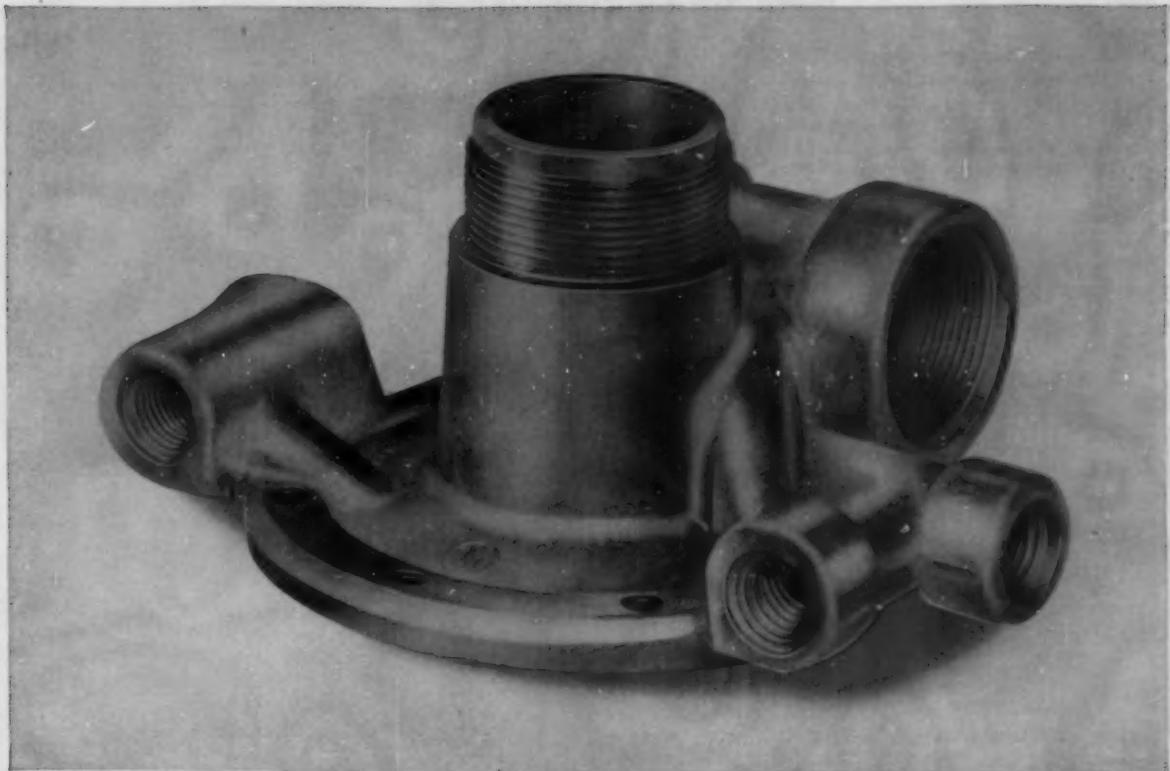
For more complete facts and technical  
information, write for Bulletin I-10:  
THE C. M. KEMP MFG. CO., 405 East  
Oliver Street, Baltimore 2, Md.

**KEMP**  
OF BALTIMORE



### INERT GAS GENERATORS

CARBURETORS • BURNERS • FIRE CHECKS  
METAL MELTING UNITS • ABSORPTIVE DRYERS  
SINTERING EQUIPMENT



Anaconda Die Pressed Brass Forging after machining, ready for assembly in the gas-pressure regulator shown below.

## Better regulators at less cost—with die pressed forgings

### Save 25% in first cost—cut machining time, tool cost

Smith Welding Equipment Corp. of Minneapolis uses Anaconda Die Pressed Brass Forgings for gas-pressure

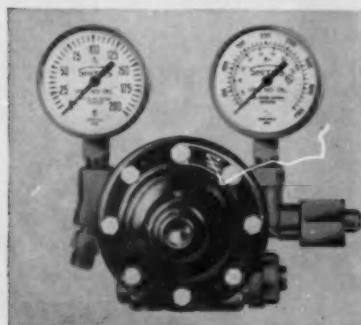
ure regulator bodies as a result of the following analysis of the job.

First, die pressed forgings make a superior product because the twice-wrought metal has the uniformity, denseness, toughness, and strength to prevent gas leaks and to withstand pressures that run in excess of 2500 psi. And second, the forgings do the job economically. The initial cost of the die pressed forging is 25 percent less than the cost of sand castings. In addition, savings are realized in substantially reduced tool costs and machining time. And finally, the forgings are finished in a simple bright-dipping operation, with savings over sand castings estimated at 5 cents a unit.

**SHORT CUTS:** Anaconda Die Pressed Forgings are short cuts to superior products. Because of their high strength, hardness and resistance to

impact, abrasion, and corrosion, they serve better functionally, often replacing more costly built-up assemblies of cast, stamped, drawn, or other machined parts. Their consistent accuracy of dimension eliminates most surface machining to size, permits trouble-free use of drilling jigs, threading or milling fixtures, broaching vises in secondary operations. They are ideally suited to high-speed automatic chucking machines.

The die pressed forging technique is practically unlimited in diversity of shape and field of application. Specialists at The American Brass Company will be glad to submit estimates on the cost of forgings for your critical components. Just submit a sketch or sample of the part involved—or write for Publication B-9. Address: The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Limited, New Toronto, Ontario.



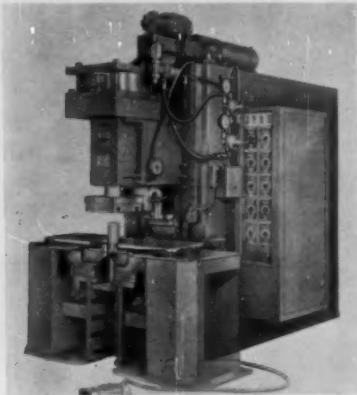
Smith's two-stage oxygen regulator, Model H313. One of the Smith Welding Equipment Corp. products using Anaconda Die Pressed Brass Forgings.

**ANACONDA® COPPER ALLOY DIE PRESSED FORGINGS**  
*Short cuts to superior products*

der rotation for best results in each solution tank. By providing gang drives at each section of the machine, the cylinders change rotation to match the tank requirements without multi-speed motors on each cylinder frame. For further information circle No. 23 on literature request card, page 48-B.

### Welder

Sciaky Bros. has announced a new design of a press-type air operated spot and projection welder. The



PMCO, 6T contains a 500 kva., 3-phase welding transformer. Maximum secondary current is 125,000 amp. as

passed through a mild steel sandwich pile of 1 in. flat, 2 in. round, and 1 in. flat. An electrode force of 25,325 lb. is attainable at 80 psi. gage.

For further information circle No. 24 on literature request card, page 48-B.

### Dip Coating

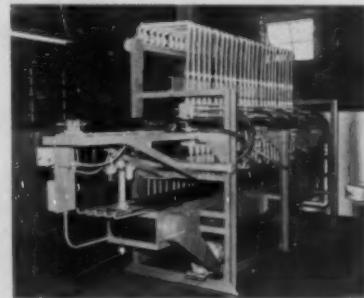
A dual hot-dip coating machine for coating wire cloth with lead or zinc has been announced by Reynolds Wire Div. of National-Standard Co. The high productivity of the machine is due to the arrangement of one roller above the other, permitting wire cloth up to 60 in. wide to be moved through successive baths of sodium hydroxide and muriatic acid, two cold water rinses and a flux pan before passing through a tank of molten metal. After the coating solidifies, an accumulator winds the wire in rolls preparatory to shipment.

For further information circle No. 25 on literature request card, page 48-B.

### Heater

A new unit for heating the centers of T-shaped heavy duty chain attachment blanks prior to making a right-angle bend has been announced by Gas Appliance Service. The heating zone consists of two opposing rows of high speed Zig-Zag burners that

heat the center part of the blank only to a temperature of 1600° F. required for bending. Production rate is 150 units per hour. The heating unit can be set up to handle a variety of blank sizes and thicknesses as the adjustable guide rails line up the blanks so



that they are always centered between the burners. Internal combustion-type burners produce a concentrated heat pattern. Ordinary city or natural gas can be used.

For further information circle No. 26 on literature request card, page 48-B.

### Thermocouple Wire Insulation

Claud S. Gordon Co. has announced a thermocouple extension wire with polyvinyl plastic insulation on each conductor and over-all polyvinyl plastic jacket. Insulation will withstand temperatures up to 220° F., does not support flame, is impervious to moisture, fungus and bacteria and unaffected by petroleum, alkalies and acids. It is suited to open runs in extremes of weather and for underground installation.

For further information circle No. 27 on literature request card, page 48-B.

## MARTINDALE



### CARBIDE ROTARY BURS

Cut toughest metals, abrasive materials, and metals too hard for ordinary high-speed tools. Precision ground from solid carbide. Each tooth lapped to provide cooler cutting, extremely long life, lower costs. Illustrated are typical shapes available in all sizes from 3/32" to 1" diameter. Complete line of high speed steel rotary burrs and files.

### MOTOR-FLEX UNITS

Most versatile general purpose power tools for grinding, burring, buffing, filing and similar production operations. Martindale units have ball bearings throughout, flexible cores made of finest spring steel, and run in rubber-covered non-shrinkable sheaths. Seven models: 24 combinations of shaft speeds and 1/10 to 1/2 H.P. to meet specific needs. Available in bench, pedestal or overhead suspension types. Complete line of attachments for all finishing operations.



### MARTINDALE ELECTRIC COMPANY

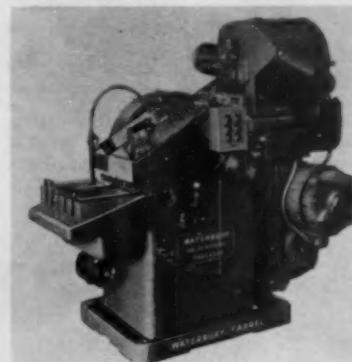
1372 Hird Avenue • Cleveland 7, Ohio

#### WRITE TODAY FOR

#### NEW CATALOG

64 PAGES

For maintenance, safety  
and production equipment



### Die Threader

A new rotary die threader designed for long or short runs has been announced by the Waterbury Farrel Foundry & Machine Co. Employing a circular die and die segment, the machine can thread all types of ma-

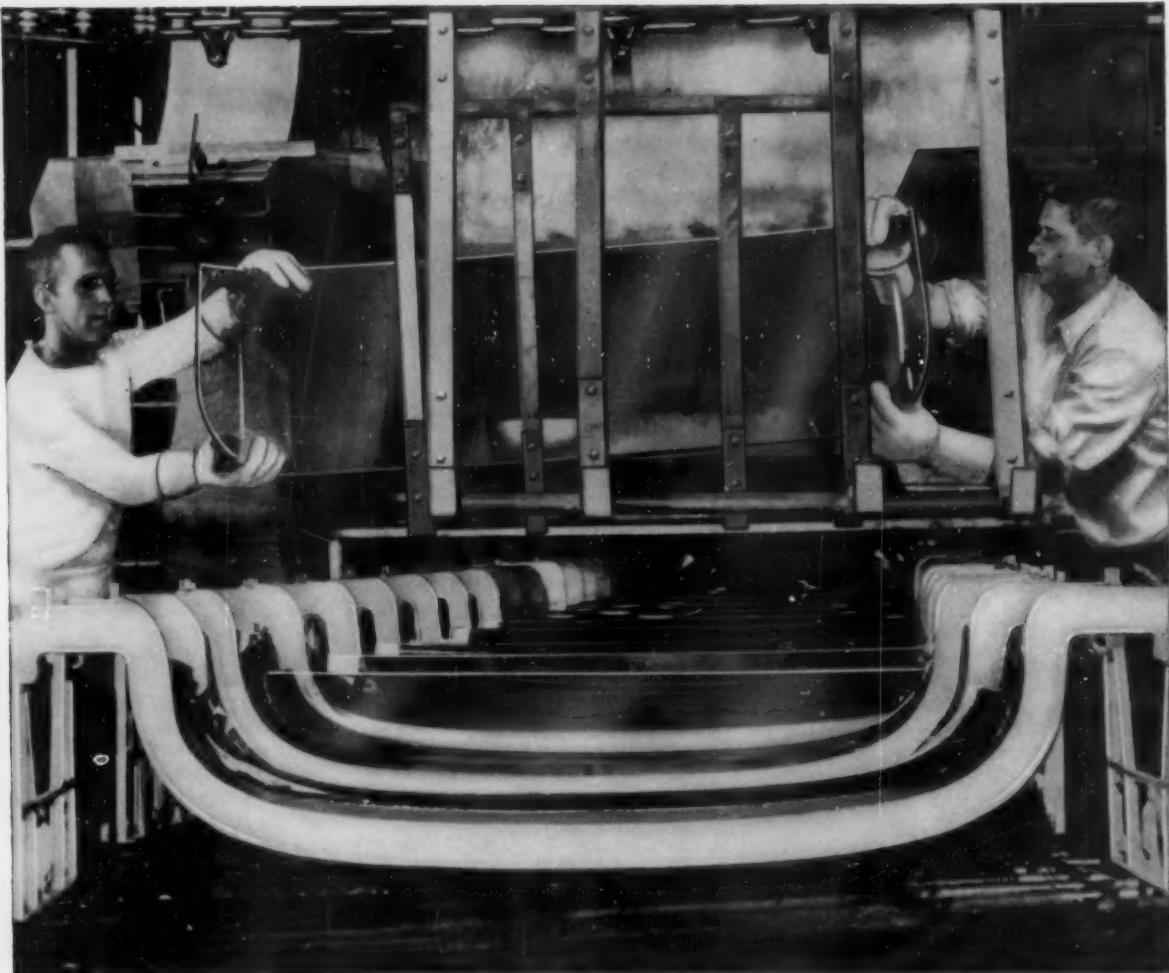
You get more  
than Quality when you specify  
**Jessop**  
**high-speed steel**



When you need a special steel that cuts fast and deep and stays sharp even when very hot, it's pretty certain you'll ask for "high-speed." And if you're looking for assurance of top quality, you are apt to name by name a company that pioneered in the business of making high-speed steels, contributed materially to their development, and has lab and quality-control techniques well ahead of the field. You're apt to specify Jessop.

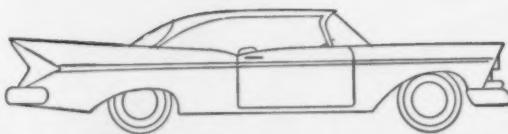
But you get more than quality when you specify Jessop high-speed steel. You get good service for two very good reasons. First, Jessop has the capacity to supply demand promptly. It can produce more high-speed products, (namely sheets, plates, bars, forgings, castings and special shapes), at one location than any other company in America. And second, Jessop wants all the high-speed steel business it can get and bends over backwards to please its customers. Send in an order and you'll find out.

**JESSOP**  
STEEL COMPANY • WASHINGTON, PA.



## Greater visibility, trimmer lines in new car styling....

### thanks to GAS



With nearly 7,000,000 cars being produced annually, the increased use of glass has demanded major production improvements in the manufacture of new panoramic windshields and back-lights.

Since the forming of the intricately curved glass is done at a temperature at which glass is soft and can be bent, the production process challenged heat process engineers to design new automatic equipment capable of mass producing these large precision glass pieces.

Selas engineers, working with the nation's leading glass manufacturer, discovered that Gas could produce the proper time-temperature cycle demanded by this

process, efficiently, quickly, reliably. The flat glass is conveyed under radiant Gas burners which bring the glass quickly up to bending temperature and allow the shaping of windshields, with reproducible uniformity, at high production rates.

The production of this wrap-around windshield is another example of the contributions modern Gas equipment is making to American manufacturing. If you have an operation demanding precise process heating, call your local Gas Company's Industrial Specialist and discuss the economies and results you, too, can get with modern Gas equipment. *American Gas Association.*

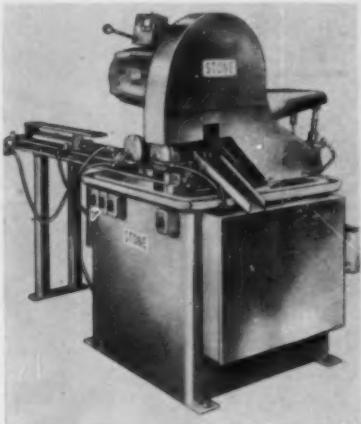
See Playhouse 90 with Julia Meade on CBS-TV. Watch local listings for time and station. Sponsored by your Gas Company and the Gas Industry.

chine screws as well as other headed parts. The threader will handle blanks from  $\frac{1}{4}$  to 2 in. long and thread diameters from No. 6 to  $\frac{1}{4}$  in. Production rates on blanks of conventional screw materials such as steel, brass and other alloys range from 200 to 600 per min. Stainless steel blanks can be threaded at from 60 to 200 per min. A separately driven rotor vane feed is used and a four step pulley arrangement allows the operator to select the feeding speed.

For further information circle No. 28 on literature request card, page 48-B.

#### Cut-Off Machine

Stone Machinery Co. has announced a new automatic cut-off machine. Powered by a 10 hp. continuous duty



induction type motor, the M-100 cuts ferrous metals with an abrasive wheel and nonferrous with a saw blade. Tolerances are held to  $\pm 0.010$  in. on production runs. An abrasive wheel wear compensator automatically adjusts for faster, more accurate cutting. The M-100 may be manually operated or semi-automatically operated.

For further information circle No. 29 on literature request card, page 48-B.

#### Temperature Controller

A new mercury actuated, air operated indicating temperature controller has been announced by the H. O. Trerice Co. It is available in two

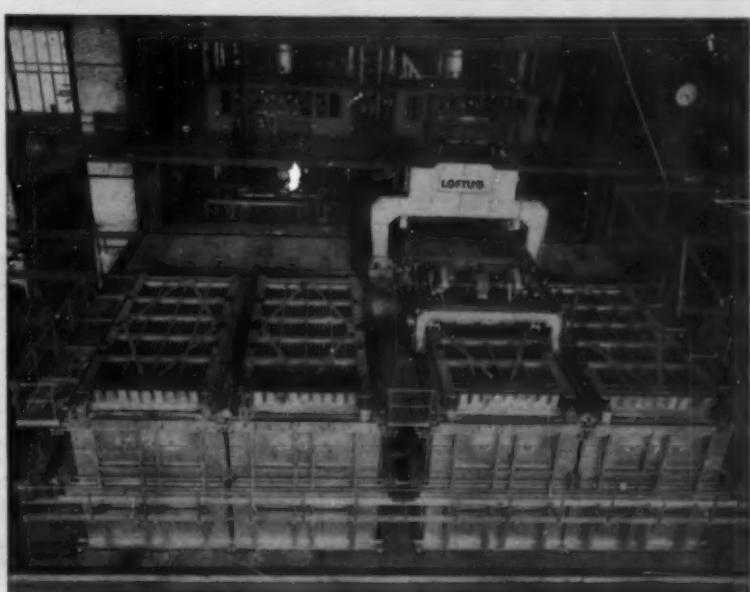


JULY 1957

basic types, on-off fixed high sensitivity or proportional band. The new controller can be changed from direct to reverse acting. The fixed high sensitivity controller is used on batch-type processes, where on-off valve cycling is satisfactory. The proportional band type offers throttling control for continuous flow processes, where cycling and over-shooting cannot be tolerated, and is particularly adaptable to applications having variable time lags and capacities and where load changes are not frequent. For further information circle No. 30 on literature request card, page 48-B.

#### Zinc Brightener

A new zinc brightener for barrel plating of small parts has been announced by Smoothex Corp. The close-grained deposits assure an underseal for finishes and protect the parts from rust and corrosion. A foundation is also provided for chromate finishing and bonderizing. Because of the wide current density range, uniform zinc deposits are made on all parts within the barrel. Plating current ranges from 60 to 90 amp. per sq. ft., depending upon the work being processed. For further information circle No. 31 on literature request card, page 48-B.



## LOFTUS PIT FURNACES

**Insure top performance for each investment dollar, with the following distinct advantages:**

- Less investment with multi-purpose cover crane
- More production with heat acceleration
- More economy with integrated recuperation
- More uniform soak with flame tempering
- More setting capacity with top firing
- More flexibility with any fuel combination
- Less maintenance with flush carriage rails

We solicit an opportunity to discuss your requirements—without obligation.

*From first heat to heat treat, look to . . .* **LOFTUS**

*Engineering Corporation*  
1 Gateway Center, Pittsburgh, Pa.  
140 S. Dearborn St., Chicago, Ill.

57-1644 A

# How **SKF** Saved in 7 Ways

and at the same time improved its roller bearing cages by using the right

## Revere Brass Strip

**SKF** Industries, Inc., Philadelphia, Pa., like other progressive organizations, is constantly seeking new ways to improve its products and at the same time cut production costs.

With this in mind they recently reviewed the kind of brass which was being used in

their spherical roller bearing cages from the standpoints of quality and fabrication. It was then that Revere's Technical Advisory Service studied the problem first-hand and made recommendations to the **SKF** production and engineering departments.



**SKF** IMPROVED TYPE "C" Spherical Roller Bearing cut away to show how the cage, made of Revere Brass Strip, fits into the bearing. Due to its advanced internal design, this bearing provides greatly increased capacity and service life.

HERE IS "window-type" cage of **SKF** Spherical Roller Bearing, made in two pieces, one for each row of rollers. Cage is made from rugged Revere Brass Strip at the Shippensburg, Pa., plant of **SKF** Industries, Inc.



The result was the adoption of specification changes in brass strip as recommended by Revere which gave **SKF** these 7 money, time and tool-saving advantages:

- 1** One bore pressing operation has been eliminated. Machining is more easily accomplished. Less machining is required.
- 2** Tool life has been increased with some speeds increased up to 100% and feeds up to 30%.
- 3** Rework due to burrs has been greatly reduced. One step less is required in the deburring operation while savings through reduced cycle time for remaining deburring operations are up to 40%.
- 4** Chips are small now . . . there is no "angel hair" to clutter work area.
- 5** Life of punch used in notching roller bearing cage has been doubled. Now a run may be completed without making tool adjustments due to sharpening tools.
- 6** Machining speeds and feeds have been substantially increased over those in machining the former alloy.
- 7** Die setters report that considerable work has been eliminated in setting up the tools used.

And, all of these money-saving things were accomplished without sacrificing quality—in fact the quality of these roller bearing cages was *improved*!

This is still another eye-opening example of Revere supplying the metal that will do the best job and with the greatest economy . . . be it brass, copper or aluminum or any one of their alloys.

Why not call in Revere's Technical Advisory Service to review your operation? It may mean money saved with an improved product to boot.

#### REVERE COPPER AND BRASS INCORPORATED

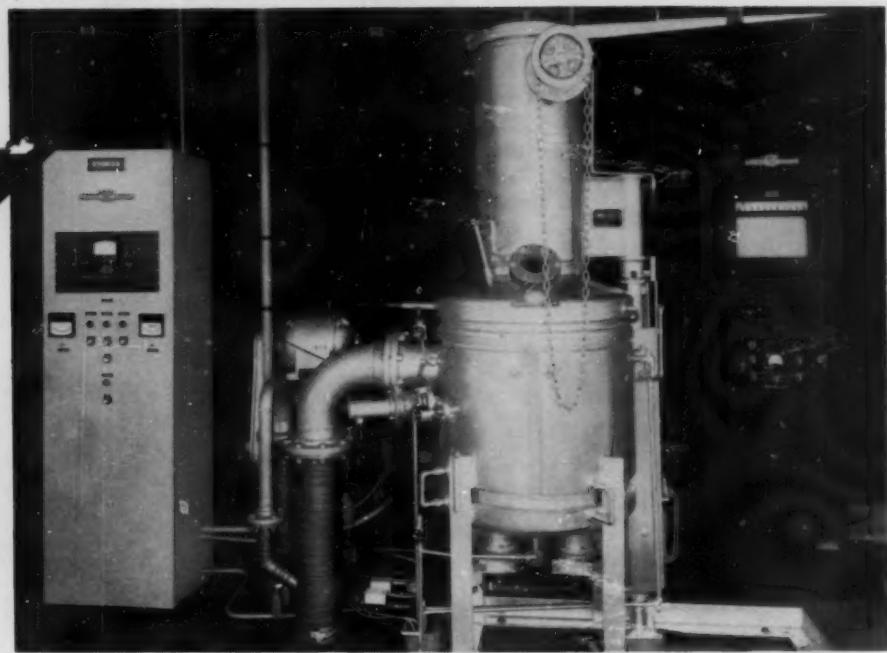
Founded by Paul Revere in 1801  
230 Park Avenue, New York 17, N.Y.

Mills: Baltimore, Md.; Brooklyn, N.Y.;  
Chicago, Clinton and Joliet, Ill.; Detroit,  
Mich.; Los Angeles and Riverside, Calif.;  
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Cities, Distributors Everywhere.



**NEW**

# HAYES Vacuum HEAT TREATING FURNACE SPEEDS UP PRODUCTION 100%!!



Model VAC-18 Vacuum Furnace Incorporates Many Unique Features for Outstanding Performance Capabilities!

## MODEL VAC-18 FEATURES . . .

- ★ Temperature Range . . . from 700°F to 2150°F.
- ★ Vacuum . . . set to operate at 0.1 micron, but will operate at different vacuums . . . as required.
- ★ Heating element of completely new design . . . operates at low voltage; allows heavier, self-supporting construction; eliminates need for refractory inside furnace.
- ★ Heating element operates on 3 phase current; arranged to come to uniform temperature; of simple construction, relatively inexpensive, and easily replaced; water-cooled leads and terminals.
- ★ "Hard-to-clean" baffles eliminated from inside unit . . . entire inner chamber of nickel-clad steel to speed up heating cycle.
- ★ Hydraulic lift raises unit head (and integral cooling chamber) to facilitate work handling.
- ★ Water-cooled, fully jacketed chamber throughout . . . except for weld areas subjected to vacuum.
- ★ Saturable Reactor type power control maintains temperature of element . . . eliminates "on-off" control.

**Metallurgical vacuum processing** advances another great step toward meeting the severe performance demands of modern industry . . . with the introduction of the new Hayes Model VAC-18 Vacuum Heat Treating Furnace. Many unique features are incorporated in its design . . . to speed up the heating and cooling cycles . . . to facilitate work handling . . . and to improve process control and work-heating qualities.

**Request complete information** on these and other design features that make the Hayes Model VAC-18 Vacuum Furnace so completely new and outstanding in performance characteristics. Improve your product, increase output, and reduce unit costs . . . with GUARANTEED RESULTS! Let us show you what over fifty years experience in developing the well known line of CERTAIN CURTAIN electric furnaces and allied equipment can do for you. Write today!!

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*Free Literature*

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| <input type="checkbox"/> Vacuum Heat Treating | <input type="checkbox"/> Stainless Steel Heat Treating    |
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| <input type="checkbox"/> Tool Steel Hardening | <input type="checkbox"/> Copper Brazing and Soldering     |
| <input type="checkbox"/> Carbo-Nitriding      | <input type="checkbox"/> Lead Pot Hardening and Tempering |
| <input type="checkbox"/> Tempering            | <input type="checkbox"/> Atmosphere Equipment             |
| <input type="checkbox"/> Bright Heat Treating | <input type="checkbox"/> Other . . . . .                  |

# APPLICATION and EQUIPMENT

## new literature

### 41. Air Washers

Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber Co.*

### 42. Alloy Castings

8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

### 43. Alloy Castings

22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

### 44. Alloy Tools

44-page book on cast Stellite tools for metal cutting. *Haynes Stellite*

### 45. Aluminum

12-page booklet on extruded shapes, tube and pipe, coiled sheet, forgings and properties of aluminum alloys. *Revere*

### 46. Aluminum Alloy

4-page brochure on alloy 417. Composition, properties, government specifications and applications. *Apex Smelting Co.*

### 47. Aluminum Die Castings

Bulletin on design and manufacture of aluminum die casting. *Hoover Co.*

### 48. Aluminum Extrusions

Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

### 49. Aluminum Heat Treating

8-page Bulletin 5912 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

### 50. Ammonia for Heat Treat

Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

### 51. Annealing Furnaces

8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

### 52. Atmosphere Control

Bulletin 5702 on atmosphere control method and how it operates in heat treatment of steel and nonferrous metals. *C. I. Hayes*

### 53. Atmosphere Control

8-page bulletin on furnaces, atmosphere equipment, controls for bright annealing, hardening and tempering, batch annealing, age hardening and carburizing. *Surface Combustion Corp.*

### 54. Atmosphere Furnace

Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

### 55. Atmospheres

12-page booklet on design and use of special atmospheres for industrial furnaces. *Continental Industrial Engineers*

### 56. Austempering

Bulletin No. 167 on mechanized salt bath installation for continuous heat treatment of farm tools. *Ajax Electric*

### 57. Black Oxide Coatings

8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

### 58. Blackening Copper

Bulletin of operating instructions for blackening and coloring copper and copper alloys. *Enthone*

### 59. Brazing

Low Temperature Brazing News, No. 76, tells about silver brazing fishing reels. *Handy & Harmon*

### 60. Brazing

16-page reprint on furnace brazing gives advantages of method, design factors and methods of handling assemblies and furnaces for brazing. *Electric Furnace*

### 61. Brazing Alloys

Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

### 62. Brazing Aluminum

Bulletin 23 on dip brazing method for aluminum. Step-by-step procedures, design techniques, fixturing arrangements. *Handy & Harmon*

### 63. Burnishing

Technical data sheet 49 on compounds for burnishing all base metals. *MacDermid*

### 64. Carbides

New 76-page catalog 56-G of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

### 65. Carbides

15 data sheets on Carbmet carbide grades. Typical applications, analysis, physical characteristics and grain structure. *Allegheny Ludlum Steel Corp.*

### 66. Carbon Brick

Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

### 67. Carburizing Steels

12-page reprint on making gears of new carburizing steels. *Climax Molybdenum*

### 68. Cemented Carbides

66-page catalog on brazed carbide tools, tool holders, inserts. Effective cutting speeds. *Machinability* computer described. *Metallurgical Products Dept., General Electric*

### 69. Chemical Analyzer

Data on Autrometer, automated chemical analyzer. Performance, applications. *Phillips Electronics, Inc.*

### 70. Chromate Finishing

File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

### 71. Chromium Plating

4-page bulletin on new "crack-free" chromium plating process. *Metal & Thermit*

### 72. Chromium Stainless

12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

### 73. Cleaner

Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

### 74. Cleaning

Data on ultrasonic cleaning equipment gives specifications and operation. *Branson Ultrasonics*

### 75. Cleaning and Finishing

12-page bulletin 68 on equipment for metal cleaning and treating describes two-stage, 3-stage and multiple-stage washers and washer heating systems. *Despatch*

### 40. Stainless Steel

This new 32-page booklet on stainless steel sheet and strip contains more than 20 tables on comparative properties, corrosion resistance of various stainless steels, fabrication properties and weight tables per lineal foot



in various widths and gages. There are sections on the selection of stainless steel grades and an industry index of applications in the automotive, food processing, dairy, chemical, textile, pulp and paper, laundry and other industries. *Allegheny Ludlum Steel Co.*

### 76. Coated Metals

New bulletin on roll coating shows how it is done and includes samples. *Roll Coater, Inc.*

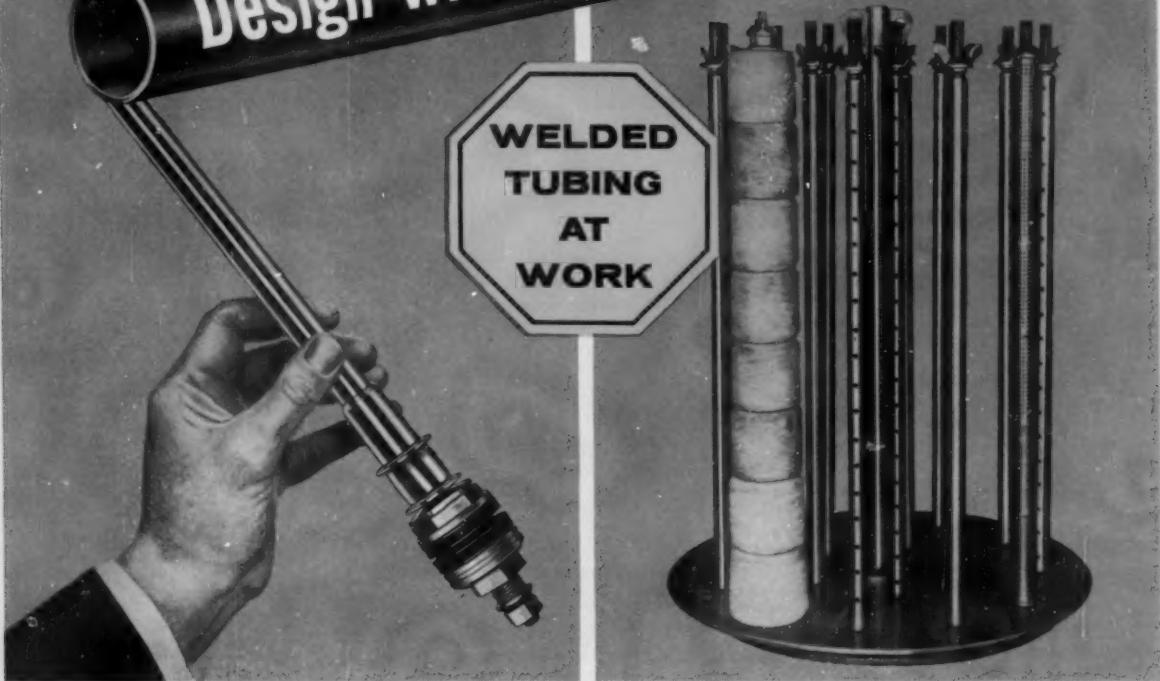
### 77. Coatings

New bulletin gives uses of various conversion coatings for zinc and cadmium. *Chemical Corp.*

### 78. Compressors

12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

# Design with TUBING in mind!



This spindle turns at 10,000 RPM without a jitter—that's the benefit of Welded Carbon Steel Tubing's "on-center" uniformity of roundness, wall thickness and concentricity.

Corrosion Resistant Welded Stainless Steel Tubing withstands constant contact with chemical dyes, pressure and wear in this packaging yarn dyeing equipment.

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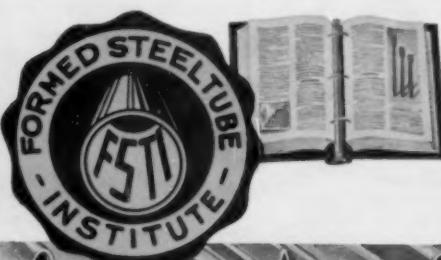
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Bulletin MF-200 on conveyor standardization describes prefabricated sections for making customized conveyors. *May-Fran Engineering*

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## 85. Copper Alloys

40-page technical data book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

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16-page bulletin on how corrosion occurs in stainless steel food processing and dairy equipment and how it can be prevented. *Diversey Corp.*

## 87. Creep Testing

Bulletin 4420 describes long-time creep test machines, creep-rupture machines and relaxation machines. *Baldwin-Lima-Hamilton*

## 88. Crucibles

Bulletin CI-55 on crucibles for service to 2900° F. *McDaniel Refractory Porcelain*

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New 12-page catalog on high-strength oxide base cutting tools. Properties, tool holders, dimensions and prices of throw-away inserts, solid inserts and unground blanks. *Stupakoff Div.*

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Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

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Bulletin on OPNT vapor degreaser describes and diagrams its construction. *Circo Equipment*

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8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

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Bulletin 25-T on salt descaling of titanium and titanium alloys. History, recommended procedure, problems. *Hooker Electrochemical*

## 94. Dew Point Control

Bulletin No. 21-C on instrument which indicates, records and controls dew point automatically. *Ipse*

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12-page bulletin on turks head, adjustable draw die. Basic types, development of turks head, various types. *Fenn Mfg. Co.*

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New bulletin on simple method of determining ductility of materials before drawing. *Steel City Testing Machines*

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Bulletin on box-type, pre-heat and

hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

## 98. Electric Furnaces

8-page bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

## 99. Electric Furnaces

8-page Carbon and Graphite News, April 1957, describes growth of electric furnace capacity. Charging developments. *National Carbon*

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12-page bulletin on box-type electric furnaces for toolroom applications. Performance data for each type. *Westinghouse Electric Corp.*

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Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

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8-page bulletin on new wire materials—Nickelplated and Brampliy, electrocoated steel wire. How it may be formed, bent and twisted without breaking the coating. *National Standard*

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20-page bulletin on Croloy welding electrodes. Specifications, coatings, applications, properties. *Champion Rivet Co.*

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Attractive literature discusses flame hardening of large ways, rolls, etc. *Detroit Flame Hardening Co.*

## 112. Flow Meters

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20-page bulletin on drop forgings describes equipment, metals and metallurgy, heat treating, cleaning and finishing. *J. H. Williams & Co.*

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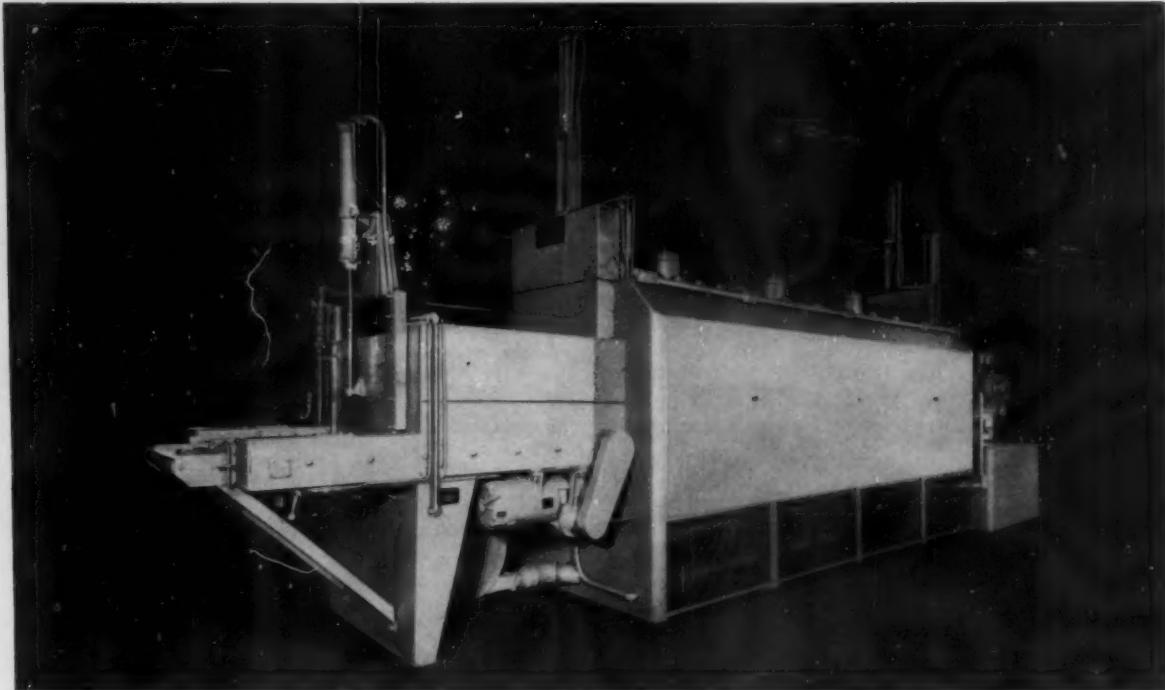
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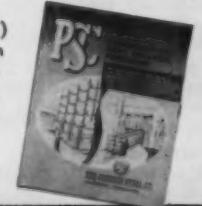
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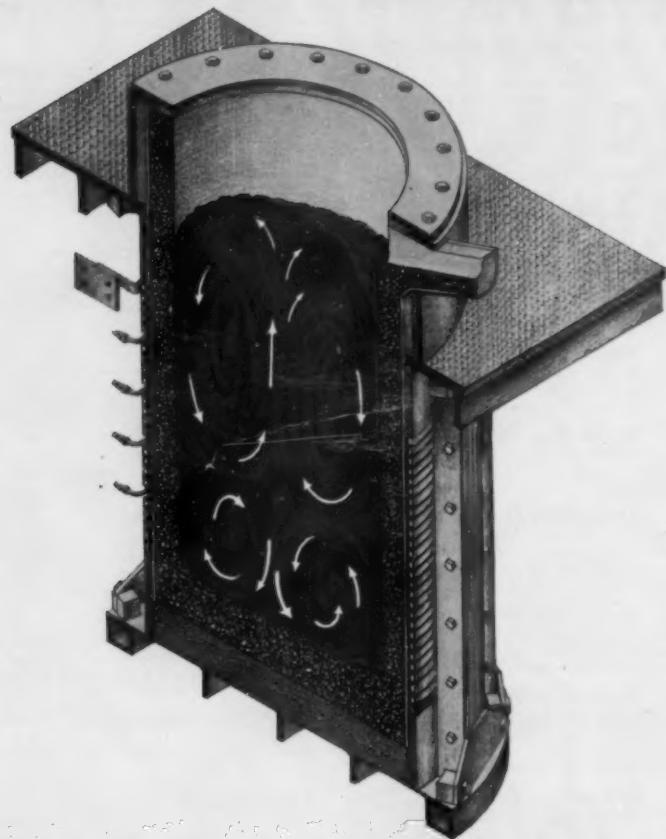
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**210. Optical Instruments**

Ways to use optical instruments in manufacturing and inspection. Magnifiers, microscopes, wide field tubes, microscopes and comparators discussed. Bausch & Lomb Optical

**211. Ores**

8-page description of the Colorado plateau, its industries, ores, mining and metallurgy. Vancoram Review, Spring-Summer, 1957. Vanadium Corp.

**212. Ovens**

New 16-page bulletin 157 on ovens for baking, drying, curing and heat treating. Batch and conveyor types. Air recirculating and heating systems. Young Brothers

**213. Pickling Baskets**

Data on baskets for degreasing, pickling, anodizing and plating. Jelliff

**214. Pickling Baskets**

12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. Youngstown Welding & Eng'g

**215. Plating Brightener**

Literature on zinc brightener used in plating parts by barrel method. Smoother

**216. Polishing Materials**

20-page booklet includes samples of emery, aluminum oxide and silicon carbide papers and 12 polishing cloths. Buehler Ltd.

**217. Porcelain Enamel**

20-page booklet reviews history of porcelain enamel and describes large volume production of small parts. Erie Ceramic Arts Co.

**218. Potentiometer**

New 6-page data sheet lists specifications and gives applications in laboratories. Leeds & Northrup Co.

**219. Powdered Metals**

Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. New Jersey Zinc

**220. Precious Metals**

Data on bright gold, bright silver, rhodium plating and salts. Sel-Rex

**221. Precision Casting**

12-page book on alloy selection and design for investment casting. Arwood

**222. Precision Casting**

8-page bulletin on investment castings of various ferrous and nonferrous alloys. Engineered Precision Casting

**223. Presses**

Data on mechanical and hydraulic powered metal presses 8 to 500-ton capacities. Haller, Inc.

**224. Protective Coatings**

Folder 301 on industrial protective coatings of rubber, neoprene and other materials. Arco Steel Fabricators

**225. Pyrometer**

12-page bulletin on contact pyrometer for surface temperatures describes and illustrates instrument and its uses. Illinois Testing Laboratories

(Continued on page 48-A.)

**WILSON "ROCKWELL"**  
THE WORLD'S STANDARD OF HARDNESS TESTING ACCURACY

**WILSON "ROCKWELL"**  
DIAMOND

**"BRALE" PENETRATORS**

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TO MEET EVERY HARDNESS  
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With WILSON Diamond "BRALE" Penetrators the accuracy built into your "ROCKWELL" hardness tester is not jeopardized. Thus, there is no danger of your rejecting good parts, passing sub-standard parts or endangering your good name with your customers. Inaccurate measurements with less expensive, inferior quality diamond penetrators are a hazard you cannot afford.

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The Model 40 Iriditron, an isotope radiography machine capable of containing 30 curies of Iridium 192, is the lightest unit manufactured that can make panoramic exposures at a distance. It is especially designed for exposures which cannot be made conveniently with X-Ray equipment.

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The Iriditron also stores the source when not in use and the shielded head serves as a shipping container.

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**NUCLEAR SYSTEMS**

A DIVISION OF THE BUDD COMPANY, Philadelphia 32

**Budd**

# Save Time, Maintenance and Money In Your Metal-Melting . . .

## Specify Norton Refractory Cements

### FOR FERROUS METAL-MELTING

| type of equipment        | metals melted                         | use of cement                     | Norton cement recommended |                      |                  | how applied       |
|--------------------------|---------------------------------------|-----------------------------------|---------------------------|----------------------|------------------|-------------------|
|                          |                                       |                                   | number                    | maturity temperature |                  |                   |
| indirect arc             | alloy iron and steels                 | lining                            | RA 1307                   | 1150°C               | 2100°F           | rammed            |
|                          |                                       | patching                          | RA 1307<br>RA 1162        | 1150°C<br>1000°C     | 2100°F<br>1850°F | rammed<br>rammed  |
| direct arc               | alloy steel and malleable iron        | troweling around electrodes       | RA 1162                   | 1000°C               | 1850°F           | trowled           |
|                          |                                       | lining roof and around electrodes | RA 1307                   | 1150°C               | 2100°F           | rammed            |
| high frequency induction | stainless steel and refractory alloys | lining                            | RM 1170                   | 1150°C               | 2100°F           | rammed (dry)      |
|                          |                                       | patching large furnaces           | RM 1152                   | 1200°C               | 2200°F           | rammed            |
|                          |                                       | patching small furnaces           | RM 1992                   | 1100°C               | 2000°F           | trowled or rammed |
| ladles                   | iron and steel                        | lining                            | RA 1307                   | 1150°C               | 2100°F           | rammed            |

### FOR NONFERROUS METAL-MELTING

|                             |                     |                     |         |        |        |        |
|-----------------------------|---------------------|---------------------|---------|--------|--------|--------|
| low frequency induction     | Al, Te, Si bronzes  | lining              | RM 1140 | 1250°C | 2300°F | rammed |
|                             | general purposes    | lining              | RA 1307 | 1150°C | 2100°F | rammed |
| indirect arc                | brasses and bronzes | lining and patching | RA 1307 | 1150°C | 2100°F | rammed |
| crucible melting furnaces ■ | brasses and bronzes | lining and patching | RC 1188 | 1100°C | 2000°F | rammed |
| reverberatory furnaces ▲    | brasses and bronzes | lining and patching | RC 1188 | 1100°C | 2000°F | rammed |

■ Cement not in contact with metal; used in combustion chamber. ▲ Cement in contact with metal.

Norton ALUNDUM\* fused alumina (RA), CRYSTOLON\* silicon carbide (RC) and MAGNORITE\* fused magnesia (RM) cements are stable and very refractory. Carefully blended to assure proper grain size distribution, they are excellent for the widest range of operations.

For complete facts as to the nature and selection of these *engineered and prescribed* Norton R's, contact your Norton Representative. He'll supply you with the booklet *Norton Refractory Cements*. Or write for your free copy to NORTON COMPANY, Refractories Division, 326 New Bond Street, Worcester 6, Mass.

\*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries



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*For best performance and maximum economy*

## **7 different specialized refractories used in annealing furnace lining**

Engineering a furnace lining with *specialized* refractories can save dollars on construction, fuel and maintenance as well as extend productive working time. To achieve these results, seven different B&W refractories were used in the lining of this 25' x 23' x 14' annealing furnace.

Fuel savings and close temperature control were made possible by using three types of *lightweight* B&W Insulating Firebrick. Walls are composed of *B&W K-23 IFB* backed up with *B&W K-16*. Because of the proximity of the burners, the roof was constructed of *B&W K-26 IFB*, a higher temperature brick to guard against the effect of possible localized overheating.

The weight saving construction means about 100 lb less refractory material to heat up per sq ft than with ordinary firebrick, or about 28 tons less in the roof of the furnace. Furthermore, supporting steel is less

massive, far less costly. Commercial size steel can be used for roof suspension instead of special steels.

To eliminate the need for expensive special shapes, the burner tunnels are formed of *B&W's 3000 F refractory castable*, *Kaocast*. Lintels over the burners and jambs are constructed of rugged *B&W Junior Firebrick*.

To take advantage of fast, easily installed castable construction, *B&W*

Nose arch, cast of B&W Kaocrete D, immediately after removing forms.

*Kaocrete-D* was used in the nose arch (separately pictured). This sturdy castable with a 2500 F use limit was selected to provide strong resistance to abrasion caused by door operation. In addition, the need for costly fired shapes and their supporting castings was eliminated, as was a great deal of expensive engineering detailing.

The car top is insulated with *B&W Kaolite-20*, a 2000 F insulating refractory concrete.

For further information, write for *B&W* bulletin R-2-H on insulating firebrick and *B&W* bulletin R-35 on castables.



(Continued from page 45)

**226. Quenching**

Catalog on two small self-contained quenching units. Bell & Gossett

**227. Radiation Badges**

Data on badges which record exposures to radiation. Picker X-Ray Corp.

**228. Radiography**

20-page bulletin on gamma radiography. Uses, sources, equipment. Nuclear Systems Div., Budd Co.

**229. Radiography**

4-page bulletin on gamma ray camera. Automatic and manual models. Tracerlab

**230. Rare Earths**

8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting." Molybdenum Corp.

**231. Rare Earths**

12-page handbook on rare earth chemicals, thorium. Applications of rare earths. Heavy Minerals Co.

**232. Recirculating Furnace**

Bulletin on continuous-type recirculating furnace shows design of furnace, its operation. Industrial Heating Equip.

**233. Refractories**

January issue of Carborundum News gives history and growth of refractories industry and Refractories Div. Carborundum Co., Refractories Division

**234. Refractories**

24-page bulletin R-35 on castables, insulating concrete mixes, plastics, ramming mixes, and mortars. Babcock & Wilcox

**235. Refractories**

24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. Norton

**236. Refractory**

Bulletin on castable refractories. How to use them. Properties of four types. Standard Fuel Engineering

**237. Refractory Metals**

8-page bulletin on titanium and zirconium castings and ingots. Corrosion properties given in 3-page table. Oregon Metallurgical Corp.

**238. Residual Stresses**

32-page, pocket-size booklet on residual stresses in cold-finished steel bars and their effect on manufactured parts. LaSalle Steel

**239. Rust Prevention**

Data sheets describe solvent type and emulsifiable type rust resisting compounds. John Swift Chemical

**240. Rust Prevention**

72-page book on cleaning, preservation, and packaging of metals. Causes of corrosion. E. F. Houghton

**241. Rust Prevention**

Bulletin No. 51 on anionic surface active agent for oil-soluble rust and corrosion inhibitors, emulsifying, wetting and dispersing agents. Sun Oil Co.

**242. Rust Removal**

Folder on new alkaline cleaning material for removal of rust, certain types of heat scale and metallic smuts. Oakite

**243. Salt Bath Furnace**

4-page reprint No. 156 on salt bath furnace for brazing and carburizing, brazing, and hardening. Ajax Electric Co.

**244. Shaker Hearth Furnace**

Bulletin HD-850A on furnace for carburizing, cyaniding, hardening. Quench system, temperature control. Hevi-Duty

**245. Shear**

Bulletin on bar and billet shear for rounds, squares, flats, billets and structures, either hot or cold. Hill Acme Co.

**246. Shearing**

16-page digest on types, sizes and grades of metal cutting knives suited to all types of metal shearing. Care and handling, cutting practice and recommended grades for various operations. Hill Acme Co., Cleveland Knife Division

**247. Shearing and Slitting**

88-page catalog on shearing knives describes different kinds, knife-setting suggestions and clearances. Tables of grinding wheel specifications, hardness conversions, standard and tin-plate gages, carbon, alloy and stainless steels. American Shear Knife Co.

**248. Shell Molding**

Leaflet on procedures for using silicone parting agents in shell molding. Advantages and limitations of all types of agents. Dow Corning Corp.

**249. Silver Brazing**

48-page manual on all aspects of silver brazing applications and problems. American Platinum Works

**250. Sintered Carbides**

24-page booklet on the characteristics of the various grades, for research and design engineers. Kennametal

**251. Sintering**

8-page folder on batch and continuous-type sintering furnaces and atmospheres for sintering. Lindberg Engineering Co.

**252. Sodium**

40-page booklet on handling metallic

sodium gives typical sodium-using processes, equipment installation, recommendations for pumping and instrumentation. U.S. Industrial Chemicals

**253. Soldering**

6-page booklet on types of solder and fluxes, 9 different soldering methods, solderability and conductability of some metals. Anchor Metal Co.

**254. Spectrograph**

New 8-page catalog on Spec-Lab. Performance and applications of three models. Jarrell-Ash

**255. Spinning**

32-page booklet shows shapes which may be produced, metals, tolerances, tools used, typical parts. Combinations of spinning and press forming. Phoenix Products Co.

**256. Springs**

8-page bulletin on spring design. Stress and deflection formulas for various types of springs. Physical properties of common spring materials. Associated Spring

**257. Stainless Fasteners**

New 24-page catalog 56-A lists sizes and types. 7000 items included. Star Stainless Screw

**258. Stainless Steel**

32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. International Nickel

**259. Stainless Steel**

24-page booklet on stainless bar and wire. Forms available, grades. Advantages, properties, fabrication, electro-polishing, ebonizing. Armcro Steel Corp.

**260. Stainless Steel**

16-page booklet on Type 430 stainless gives physical properties and analysis, corrosion resistance, fabrication, application and care. Washington Steel

**261. Stainless Strip**

32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, physical and mechanical properties, corrosion resistance. Superior Steel Corp.

**262. Stainless Tubing**

New 12-page brochure on stainless steel heat exchanger and condenser tubes. Manufacturer, chemical composition and analysis. Republic Steel

**263. Stainless Wire**

32-page aid to selection of proper stainless steel wire for particular application discusses austenitic, ferritic and martensitic grades. Crucible Steel

**264. Stamping Presses**

12-page catalog on 200-ton high-speed

## CONVAIR FURNACE-BRAZES B-58 HONEYCOMB PANELS



America's first supersonic bomber  
—the U.S. Air Force B-58 Hustler  
—on a test flight from the Fort  
Worth plant of Convair Division,  
General Dynamics Corporation.

When a bomber is designed for supersonic speeds as well as altitudes above 50,000 feet the combination of weight and strength becomes vitally important.

That's why Convair uses honeycomb "sandwich" construction for wing and fuselage panels. In producing these panels, honeycomb sections are placed in frames, faced with a silver-manganese alloy brazing foil, and then covered with skins. (Honeycombs, end closures, frames and skins are all of stainless steel.)

Assemblies are then loaded into a large alloy retort mounted on a furnace car and then travel through a brazing furnace installation designed and built by Holcroft. The result is a complete bond of all stainless steel parts.

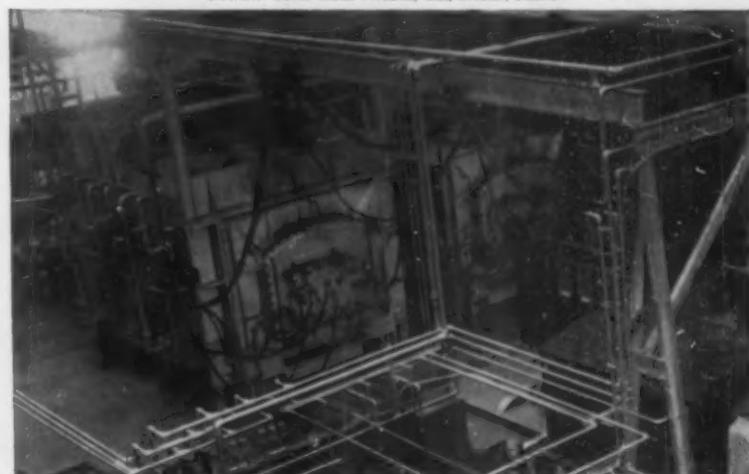
Many manufacturers are taking a tip from the aircraft industry and are applying honeycomb construction to their own products. And more and more of these manufacturers are turning to Holcroft—not only for help in developing brazing systems but for all heat treating answers as well. You can, too. Just write.

### HOLCROFT AND COMPANY



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PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

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# CMP

## RESTRICTED SPECIFICATION

### COLD ROLLED STRIP STEEL



|                     |                        |
|---------------------|------------------------|
| SIZE                | 8 x .045               |
| ANALYSIS            | 1010                   |
| FINISH              | #2 finish              |
| HARDNESS            | Non-Scalloping quality |
| THICKNESS TOLERANCE | ± .0005 incl. crown    |
| WIDTH TOLERANCE     | ± .005                 |
| COIL SIZE           | 250# per inch of width |
| PACKAGING           | Skidded                |



|                     |   |
|---------------------|---|
| SIZE                | 12 x .032                               |
| ANALYSIS            | 1010                                    |
| FINISH              | #3 finish                               |
| HARDNESS            | #4 Tempered                             |
| THICKNESS TOLERANCE | ± .0005 incl. crown                     |
| WIDTH TOLERANCE     | ± .005                                  |
| COIL SIZE           | up to 200# per inch of width            |
| PACKAGING           | Paper inter-leaved—skidded and shrouded |



Many times, by varying processing methods, CMP is able to develop properties in cold rolled strip steel which greatly facilitate production operations and/or give the product superior qualities without adding to end product cost. End result is lower costs through improved products or better assembly and improved yield.

We believe you will find it worthwhile to investigate the possibilities of CMP Restricted Specification Cold Rolled Strip Steel applied to your production.

#### CMP PRODUCTS

Low Carbon, High Carbon—Annealed or Tempered, Stainless, Alloy, Electro Zinc Coated.



**THE COLD METAL PRODUCTS CO.**  
GENERAL OFFICES: YOUNGSTOWN 1, OHIO  
PLANTS: YOUNGSTOWN, INDIANAPOLIS AND LOS ANGELES  
SALES OFFICES: NEW YORK - CLEVELAND - DETROIT - INDIANAPOLIS  
CHICAGO - LOS ANGELES - SAN FRANCISCO

*Serves Typical  
Low Carbon  
End Use  
Requirements  
Such as these..*

|                     |                     |
|---------------------|---------------------|
| SIZE                | 4 x .005            |
| ANALYSIS            | 1010                |
| FINISH              | #2 finish           |
| HARDNESS            | #3 Tempered         |
| THICKNESS TOLERANCE | ± .0005 incl. crown |
| WIDTH TOLERANCE     | ± .005              |
| COIL SIZE           | Cut lengths         |
| PACKAGING           | Skidded             |

#### THE 3 IN 1 SOURCE FOR YOUR COLD ROLLED STRIP STEEL

Now there are three CMP plants with facilities for production of "Restricted Specification" cold rolled strip. Strategic locations at Youngstown, Indianapolis and Los Angeles, provide the security of 3 sources of supply plus the close working relationship which these local production centers make possible.

automatic stamping presses. Engineering drawings and specifications. *Alpha Press*

#### 265. Stampings

16-page brochure on story of stamping. Handy tabular data. *Republic Steel*

#### 266. Stampings

New 6-page bulletin on intricate progressive stampings. Machines and equipment for their production. *Atlantic Tool*

#### 267. Steel

Bulletin on Yoloy "S" steel. Properties, welding, chemical analysis, corrosion resistance, strength. *Youngstown Sheet and Tube Co.*

#### 268. Steel Bars

Folder gives machinability of C-1144 strain-tempered steel. *Bliss & Laughlin*

#### 269. Steel Castings

8-page quarterly gives tips on selection of steel castings. Applications of castings. Case histories. *Dodge Steel Co.*

#### 270. Stereomicroscopes

38-page catalog D-15 shows value of three-dimensional microscopes for industrial assembly lines and research laboratories. *Bausch & Lomb Optical*

#### 271. Stripping

3-page usage and instruction sheet on two acid electrolytic stripping compounds. How they are used. *MacDermid, Inc.*

#### 272. Sulphur Determination

Literature on 3-min. determinator for use with combustion furnace. *Dieterl*

#### 273. Temperature Measuring

Bulletins on Tempilstiks and Tempilaq describe products and tell how to use them. *Tempil Corp.*

#### 274. Test Bars

18-page bulletin No. 168 on design of test bar patterns, production of test bars, testing procedures. *Federated Metals*

#### 275. Testing Machines

12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

#### 276. Testing Machines

40-page bulletin on electrostatic universal testing machines. Loading, weighing and indicating systems. *Tinius Olsen*

#### 277. Thermocouple Alloys

20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

#### 278. Thermocouple Assemblies

New Bulletin No. TA-457 gives sizes, prices, ordering information. *Claud S. Gordon*

#### 279. Thermocouple Data

New bulletin F-5228-3 on construction and application of thermocouples and radiation detectors to industrial control. How to check, make, select and size thermocouples. *Wheelco*

#### 280. Thickness Gage

Folder on pocket-size gage. How to use it. *Ferro Corp.*

#### 281. Titanium

8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with stainless and aluminum in various mediums. *Mallory Sharon*

#### 282. Titanium Alloy

12-page booklet on C-120AV titanium alloy. Physical properties, elevated-temperature properties, creep, fatigue, welding, machining, heat treatment. *Rem-Cru*

#### 283. Tool and Die Steels

26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem*

#### 284. Tool Steel

44-page book on tool steels for the nonmetallurgist explains the six basic kinds of tool steel and their heat treatment. *Crucible Steel*

#### 285. Tool Steel

Wall chart showing more than 300 varieties of tool steel with trade name of manufacturers. *Vulcan Crucible Steel*

#### 286. Tool Steels

Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

#### 287. Tubing

Chart gives tolerances for seamless and welded mechanical and stainless tubing. *Peter A. Frasse*

#### 288. Tubing

28-page catalog on stainless and high alloy pipe and tubing from  $\frac{1}{2}$  to 40 in. dia. Contour welding. *Trent Tube*

#### 289. Ultra Strength Steel

Results of three year research and test program evaluating properties of Type 4340 steel for aircraft structures. *International Nickel*

#### 290. Vacuum Furnaces

Bulletins P-20 and P-28 on vacuum melting furnaces and pumps. *Consolidated Electrodynamics*

#### 291. Vacuum Melting

8-page bulletin on production and testing equipment for vacuum melting. Advantage. *Utica Metals Div.*

#### 292. Vacuum Metals

File of data on vacuum-melted metals and their applications for bearings and the chemical industry. Development of the vacuum metals. *Vacuum Metals Corp.*

#### 293. Vacuum Pumps

New 28-page catalog No. 752 contains specifications, tables of formulas, constants and conversion factors. Maintenance procedures. *F. J. Stokes*

#### 294. Wear Testing

Bulletin 106 on lubricant-friction-wear testing machine. How machine operates. Specifications. *Alpha Molykote Corp.*

#### 295. Welded Tubing

12-page booklet on electric-resistance welded steel tubing. Size and gage range charts for square-welded, hot and cold and rectangular-welded, hot and cold rolled tubing. *Revere*

#### 296. Welding

New 12-page bulletin on hydraulic controls for flash-butt welding machines. Manual, semi-automatic and fully automatic operation. *Taylor-Winfield Corp.*

#### 297. Welding Electrodes

28-page booklet RW-10 on resistance welding electrodes and accessories. Applications, specifications. *Ampco*

#### 298. Welding Electrodes

84-page pocket-size booklet describes characteristics, coating, sizes of various electrodes and compares them with standard designations and other electrode brand names. *Harnischfeger*

#### 299. Welding Electrodes

40-page catalog on welding electrodes, including mild steel, stainless, iron powder, high tensile and others. Tables of standard analyses. *Champion Rivet*

#### 300. Welding Equipment

Catalog on Cadweld process and arc-welding accessories. *Erico Products*

#### 301. Wire Cloth

No. 3 of The Cambridge Wire gives applications of wire cloth in ceramics, metallurgy, food, chemical and other industries. *Cambridge Wire Cloth*

#### 302. X-Ray Supplies

Bulletin on X-ray films and chemicals for radiography. *Anasco*

#### 303. Zirconium

Memo 112 on zirconium and zirconium alloys. Properties, tubing tolerances and production limits, fabrication, corrosion resistance. *Superior Tube Co.*

#### 304. Zirconium

12-page booklet on uses, properties and methods of production of zirconium and hafnium. *U.S. Industrial Chemicals Co.*

JULY, 1957

|    |    |    |     |     |     |     |     |     |     |     |     |
|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | 27 | 53 | 79  | 105 | 131 | 157 | 183 | 209 | 235 | 261 | 287 |
| 2  | 28 | 54 | 80  | 106 | 132 | 158 | 184 | 210 | 236 | 262 | 288 |
| 3  | 29 | 55 | 81  | 107 | 133 | 159 | 185 | 211 | 237 | 263 | 289 |
| 4  | 30 | 56 | 82  | 108 | 134 | 160 | 186 | 212 | 238 | 264 | 290 |
| 5  | 31 | 57 | 83  | 109 | 135 | 161 | 187 | 213 | 239 | 265 | 291 |
| 6  | 32 | 58 | 84  | 110 | 136 | 162 | 188 | 214 | 240 | 266 | 292 |
| 7  | 33 | 59 | 85  | 111 | 137 | 163 | 189 | 215 | 241 | 267 | 293 |
| 8  | 34 | 60 | 86  | 112 | 138 | 164 | 190 | 216 | 242 | 268 | 294 |
| 9  | 35 | 61 | 87  | 113 | 139 | 165 | 191 | 217 | 243 | 269 | 295 |
| 10 | 36 | 62 | 88  | 114 | 140 | 166 | 192 | 218 | 244 | 270 | 296 |
| 11 | 37 | 63 | 89  | 115 | 141 | 167 | 193 | 219 | 245 | 271 | 297 |
| 12 | 38 | 64 | 90  | 116 | 142 | 168 | 194 | 220 | 246 | 272 | 298 |
| 13 | 39 | 65 | 91  | 117 | 143 | 169 | 195 | 221 | 247 | 273 | 299 |
| 14 | 40 | 66 | 92  | 118 | 144 | 170 | 196 | 222 | 248 | 274 | 300 |
| 15 | 41 | 67 | 93  | 119 | 145 | 171 | 197 | 223 | 249 | 275 | 301 |
| 16 | 42 | 68 | 94  | 120 | 146 | 172 | 198 | 224 | 250 | 276 | 302 |
| 17 | 43 | 69 | 95  | 121 | 147 | 173 | 199 | 225 | 251 | 277 | 303 |
| 18 | 44 | 70 | 96  | 122 | 148 | 174 | 200 | 226 | 252 | 278 | 304 |
| 19 | 45 | 71 | 97  | 123 | 149 | 175 | 201 | 227 | 253 | 279 |     |
| 20 | 46 | 72 | 98  | 124 | 150 | 176 | 202 | 228 | 254 | 280 |     |
| 21 | 47 | 73 | 99  | 125 | 151 | 177 | 203 | 229 | 255 | 281 |     |
| 22 | 48 | 74 | 100 | 126 | 152 | 178 | 204 | 230 | 256 | 282 |     |
| 23 | 49 | 75 | 101 | 127 | 153 | 179 | 205 | 231 | 257 | 283 |     |
| 24 | 50 | 76 | 102 | 128 | 154 | 180 | 206 | 232 | 258 | 284 |     |
| 25 | 51 | 77 | 103 | 129 | 155 | 181 | 207 | 233 | 259 | 285 |     |
| 26 | 52 | 78 | 104 | 130 | 156 | 182 | 208 | 234 | 260 | 286 |     |

City and State

Postcard must be mailed prior to Oct. 1, 1957. Students should write direct to manufacturers.

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Company



## **no unknowns here to contaminate your alloy steels**

In raw materials, this is as far as you can get from the contamination hazard present in loose or bundled nickel scrap.

It's as close as you can get to perfection . . . weight and certified analysis in plain view at all times . . . an all fiberboard palletized package ready to go into the electric furnace — without opening.

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**World's largest producer of secondary nickel alloys of certified analysis**



Melvin L. Bleiberg, at Bettis Laboratory since 1952, operates the specially designed cooling system for his unique low temperature in-pile cryostat. Mr. Bleiberg is a member of the Solid State Studies Group, which works on fundamental metallurgical projects at Bettis. He received his master's degree in metallurgy from the University of Pittsburgh under the Westinghouse educational assistance program.

Inset shows sample chamber heat exchanger before being enclosed in an aluminum housing. The coolant gas enters the chamber from the aluminum tubing and circulates through the heat exchanger which is a double-pitch, double threaded screw. The test samples are enclosed inside this heat exchanger.

## THE RESEARCH AND DEVELOPMENT OF NUCLEAR FUELS

# A Study of Property Changes under Radiation at Low Temperatures

Nuclear fuel materials undergo drastic property changes due to neutron irradiation. Metallurgists at Bettis Atomic Power Division are actively conducting research in this new field of nuclear energy.

One typical experiment is the determination of the property changes of fissionable materials in-pile at low temperature. This unique study is based on previous work done by metallurgists at Bettis Plant\* which showed that uranium-based alloys exhibit phase changes due to the influence of neutron bombardment.

In order to study this phenomenon, a special experimental facility had been designed to obtain and sustain low temperature during irradiation of fissionable material. How to remove the heat generated by fissioning of uranium was the major problem in this experiment. M. L. Bleiberg, senior engineer, solved the problem by developing a cryostat in which specimens of fissionable materials could be maintained at temperature of less

than  $-100^{\circ}$  C. by means of flowing helium gas cooled by liquid nitrogen.

The first cryostat will be inserted into the reactor at Brookhaven National Laboratory, where it will become a semi-permanent facility to test different samples of nuclear materials. The data obtained from these tests will be used to develop improved fuel alloys for the nuclear reactors now being designed and developed at Bettis Atomic Power Division.

This is only one example of the challenging work conducted here. We welcome inquiries from metallurgists interested in the excellent careers offered by the new and growing nuclear power industry. Please address your résumés to: Mr. M. J. Downey, Department A-171, Bettis Atomic Power Division, Westinghouse Electric Corporation, P.O. Box 1468, Pittsburgh 30, Pennsylvania.

\*M. L. Bleiberg, L. J. Jones, B. Lustman, "Phase Changes in Pile-Irradiated Uranium Base Alloys," *Journal of Applied Physics*, Volume 27, p. 1270-83 (1956).

**BETTIS ATOMIC POWER DIVISION**  
**Westinghouse**

Next month—Metallurgical Process Development—Weld-Conditioning of Reactive Metals for Nuclear Applications

# Republic Titanium Flies with



The B-58 is built for the Air Force by Convair, A Division of General Dynamics Corporation, Fort Worth, Texas. Powered by four General Electric J-79 engines, the plane is designed to operate at altitudes above 50,000 feet. Photo at left is one of the first showing detachable pod under fuselage. This feature permits performance of a greater variety of missions.

# REPUBLIC



*World's Widest Range of Standard Steels*

# Convair's B-58 Hustler

## Republic titanium alloys used for elevated temperature applications and weight saving in America's first Supersonic Bomber

The delta-winged B-58's transformation from drawing board to production in record-breaking time is a tribute to the design-and-engineering skill of Convair Division, General Dynamics Corporation.

This dream plane incorporates the most advanced equipment and utilizes the latest engineering materials, including Republic Titanium.

Titanium alloy types produced by Republic Steel are used in the B-58 for weight saving and elevated temperature applications. These particular titanium alloys are among the strongest now being produced. They offer high strength values at elevated temperatures.

These alloy types have a minimum tensile strength of 130,000 p.s.i. and a minimum yield strength of 120,000 p.s.i. They meet the demand for high strength to resist the effects of aerodynamic heating in supersonic aircraft, such as the B-58.

The Hustler is the world's fastest bomber. What about the future? Right now, planes are being designed for speeds of Mach 3 or 4. Republic is keeping pace. At the Titanium Research Laboratory in Canton, Ohio, new titanium alloys are being developed with better physicals to provide greater operating efficiencies.

In exploring the "thermal thicket", many materials must be appraised and utilized. Republic—world's largest producer of aircraft steels—is working on new high-tensile, stainless types with higher strength and greater heat-resistance.

Republic metallurgists and engineers pioneered the development of high strength-to-weight metals. They offer you years of experience gained through helping hundreds of manufacturers design and redesign their products to get more strength with less weight at less cost. Contact your local Republic sales office for more information. Or send us the coupon.

MORE REPUBLIC PRODUCTS WITH ADVANTAGES FOR DESIGNERS AND EQUIPMENT BUILDERS



STRUCTURAL APPLICATION PROBLEMS requiring low weight plus high strength are best solved using tubular construction. A good example is this rocket sled designed to withstand extreme forces of abrupt deceleration. Republic ELECTRUNITE® Steel Mechanical Tubing is ideal for such an application. Uniform in wall thickness, concentricity, strength and ductility, it permits reduction in bulk without sacrifice of safety. Send coupon for more facts.



ALLOY STEEL IN THE NORTH AMERICAN F-100 landing-gear struts provides strength, toughness, maximum resistance to fatigue. Exacting requirements for inner and outer cylinders resulted in the development of a new grade of steel by Bendix Aviation Corporation and Republic metallurgists working with North American engineers. This new steel, designated AMS 6427, was found ideal for application in the strength range of 220,000-240,000 p.s.i. It maintains its great strength at wide temperature extremes. Write for more information on alloy steels.

### REPUBLIC STEEL CORPORATION

DEPT. C-4050A  
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Have a metallurgist call.  Titanium  Alloy  Stainless

Send more information on:

Titanium  Alloy Steels  
 ELECTRUNITE Mechanical Tubing

Name \_\_\_\_\_ Title \_\_\_\_\_

Company \_\_\_\_\_

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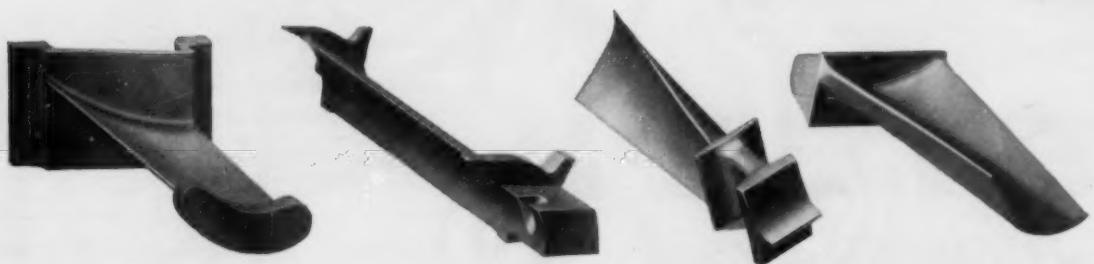
City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_

# STEEL

and Steel Products



Typical precision castings which Austenal, Inc., Microcast Division, plans to produce with new Stokes Model 437-520 vacuum furnaces.



# Here's a Really New Vacuum Furnace

---

## for "all-out" production of precision castings

Stokes precision casting furnaces—capable of melting and pouring single casts of up to 30 pounds, under vacuums as low as 1 micron or less—are custom-designed and engineered to incorporate many operating features specially requested by precision casters. Units are in operation with charging and mold locks for semi-continuous production.

### This low-cost "package" unit:

- pours smoothly... has a manually-operated tilting mechanism that operates easily.
- has good visibility... operator watches pour closely through 3-inch diameter shuttered sight glass.
- is easily operated... efficiently grouped controls cut operator's movements. Popular tandem units are operated by one man.
- can be set up for repetitive pre-determined melting and pouring cycles... interlocked, fail-safe controls permit operation by a normally skilled workman.
- provides accurate control over pouring temperatures... regularity of heat cycles cuts gage-watching time.
- takes up little floor space... measures 6'10" wide, 7'3" deep.

Others are taking advantage of Stokes advanced vacuum furnace technology in induction and arc melting, heat-treating and sintering. Isn't it time for you to contact Stokes for a discussion of your own profit-making opportunities?

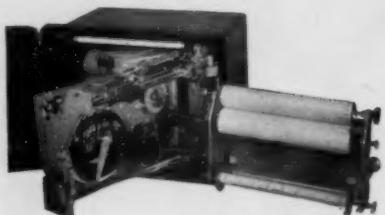
*Vacuum Equipment Division*  
F. J. STOKES CORPORATION  
5500 Tabor Road, Philadelphia 20, Pa.

**STOKES**

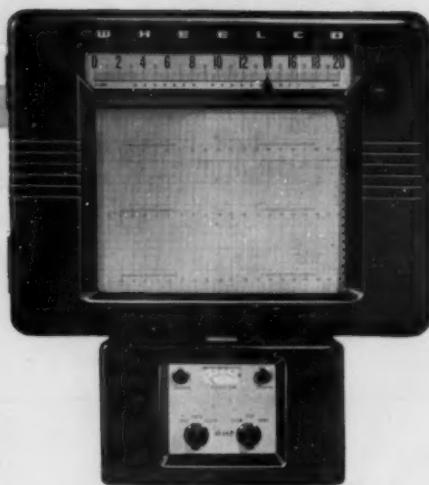
THE MARK OF QUALITY



Wheelco  
Instruments



**Series 8000 Recorders and Recording Controllers** — available in a wide range of models, these self-contained null-balancing electronic instruments feature convenient swing-out design for easy chart and instrument maintenance. Multi-point recorders keep permanent records of up to 16 points on a single chart . . . feature up to six limit switches for high and/or low signal indications . . . single- or multi-color printing . . . 3 to 24 in. per hr recording speeds.



**Automatic Reset for Recording Controllers** — available with Series 8000 instruments for demanding processes where small capacitance requires wide proportional settings and where offset cannot be tolerated. Tamperproof cover protects all adjustments, leaves controls available to operator.



The instruments shown on these pages are only representative of the many models featuring advance design and precision engineering developed through Barber-Colman's years of experience, serving practically every industry using measurement and control.

Here is one wholly dependable source on which you can standardize for the accuracy you need in precisely the form best suited to every given process. Whether you need a single instrument or a control center, you just identify your process to your broadly experi-

enced Wheelco engineer. He recommends simpler, lower cost instruments where accuracy and uniformity are less critical, offers custom-engineered control forms to meet special requirements. You are assured of unsurpassed accuracy of control for precision processes.

High-quality materials and rugged construction, use of plug-in components wherever possible, special accessibility features, and large easy-to-read indicators are other "plusses." Specify Wheelco for a *new measure* of reliability, economy, and convenience.

# of process control

with accurate, reliable, trouble-free  
**WHEELCO recorders, controllers,  
indicators, accessories, or complete  
control centers**



**Series 150 Amplitrols** — potentiometer-type controllers — offer precise control of batch-type heating at minimum cost. Model 151 is on-off controller, Model 152 provides anticipatory, time-proportioning control. The electronic circuit has been designed to "fail safe" in event of failure of any integral part.



**Packaged Control Centers**, like the one shown on the right, are designed and manufactured by Wheelco to meet industry's control needs precisely and economically. A prewired, prefabricated Wheelco control center saves you money by simplifying installation and incorporates your instruments and accessories for convenient and efficient use in an attractive panel board or heavy steel cabinet. Discuss this important modern approach to instrumentation with your nearby Wheelco field engineer!



**Wheelco Capacitrols** — completely self-contained direct-deflection-type electronic indicating controllers. Sensitive no-drift control appropriate to a variety of processes is assured by range of models, available both in vertical 400 Series (left) and in horizontal "Panelmount" types (above). Available in a variety of control forms, such as time-proportioning, two-position, Multronic, proportional-position, and electrical-proportioning. Both styles available as Limitrols — with built-in automatic shutoff.



**Indicating Pyrometers** — built to highest standards for precision instruments . . . feature meter movement with Alnico V magnet and electrical compensators for resistance changes in the metering system.



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# WHAT'S NEW ON ZIRCONIUM?

*This U.S.I. booklet gives you information  
you can use . . . Send for a copy!*

Today, with zirconium production trending sharply upward, and price downward, interest in this new and unique metal is growing rapidly.

To answer your questions about zirconium and its relative, hafnium, U.S.I. has prepared an informative new booklet — "ZIRCONIUM and HAFNIUM." The booklet gives the important facts on these newly available metals . . . lists important mechanical and physical properties of both . . . describes briefly the new semi-continuous sodium reduction process for production of zirconium and hafnium.

You'll find the outstanding corrosion proper-

ties of zirconium compared with other important metals... phase diagrams of twenty binary alloy systems . . . descriptions of several fabrication techniques.

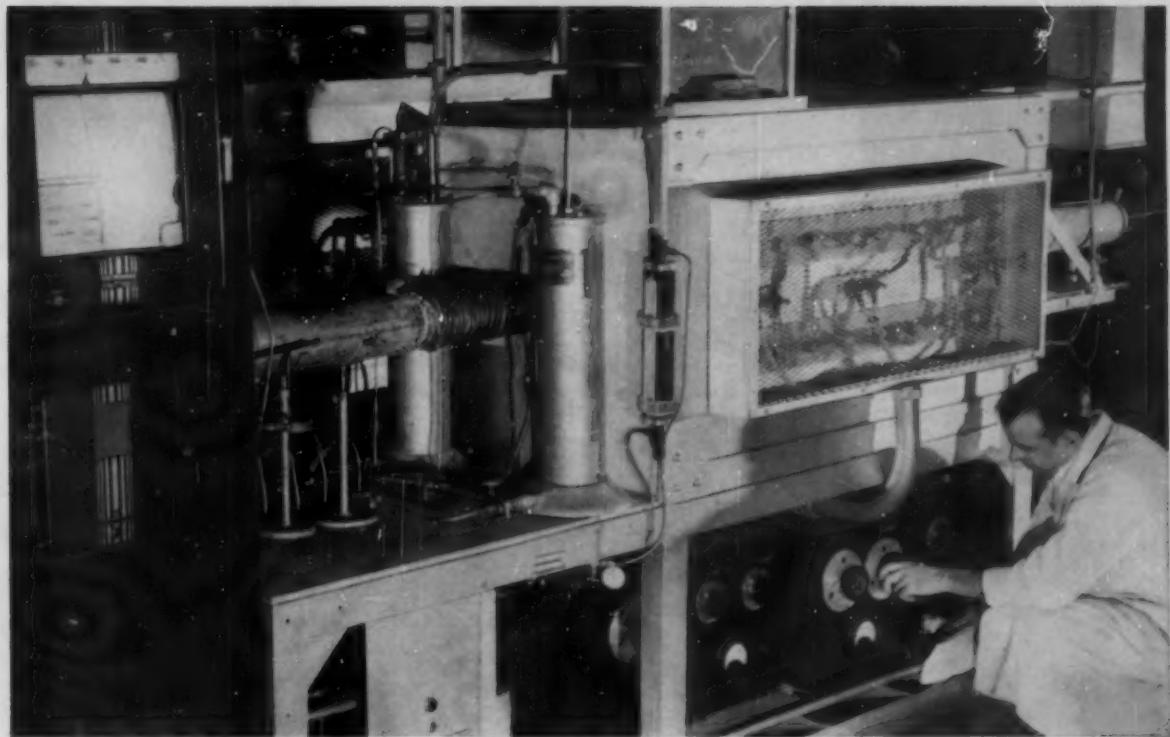
You're sure to find "ZIRCONIUM and HAFNIUM" valuable in discussions and as a preliminary reference. For your copy, forward the coupon today . . . or just send your name on your company's letterhead.



The logo for U.S.I. Industrial Chemicals Co. features a stylized oval containing the letters "U.S.I." in a bold, blocky font. To the right of the oval, the words "INDUSTRIAL CHEMICALS CO." are written in a bold, sans-serif font. Below this, the text "Division of National Distillers and Chemical Corp." is in a smaller, regular font. Underneath that, "99 Park Ave., New York 16, N. Y." is also in a smaller, regular font. At the bottom right, the words "Branches in principal cities" are written in a regular font.

**Please send me a copy of "ZIRCONIUM and HAFNIUM"**

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Title \_\_\_\_\_  
Company \_\_\_\_\_  
Street \_\_\_\_\_  
City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_



**Continuous-type tubular muffle furnace.**  
Inconel alloy muffles take thermal shock and temperatures in the 2300°F. to 2400°F. range

... save Sylvania \$3000 annually in down-time and replacement costs. Muffles are supported by contoured refractory bricks.

## Inconel muffle produces sinter at 2400°F...and saves \$3000 per year

Sylvania-Corning Nuclear Corporation, Bayside, N. Y., uses a high temperature sintering technique to make stainless steel parts.

A lot depends on the furnace muffle.

For one thing it has to take temperatures in the 2300° to 2400°F range.

For another, it has to withstand thermal shock when the cold sintering boat is stoked into the hot furnace. Cracks can't be tolerated either, because a controlled atmosphere is maintained.

*An Inconel\* nickel-chromium alloy muffle is the answer. It handles the high temperatures... withstands the thermal shock... saves this producer \$3000 annually in downtime and replacement costs.*

### Inconel alloy properties key to muffle performance

Inconel alloy retains its useful strength at extremely high temperatures... shows exceptional resistance to oxidation, too.

*Inconel alloy welds and forms easily, too. You can make it into*

practically any shape. Sylvania-Corning Nuclear Corporation use their Inconel alloy muffles in a variety of shapes: round, rectangular and square.

For particulars on the advantages and economies of Inconel alloy, write for "Keeping Costs Down... As Temperatures Go Up."

\*Registered trademark

**The International Nickel Company, Inc.**  
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New York 5, N. Y.

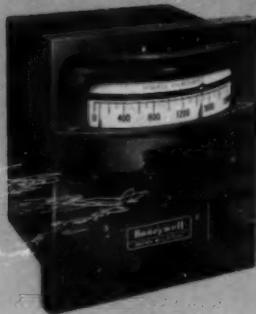


**NICKEL ALLOYS**

**Inconel**...for long life at high temperatures



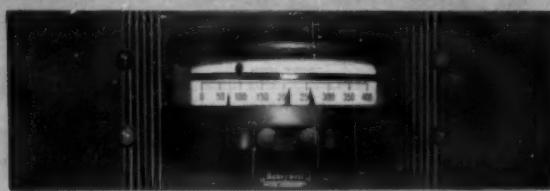
**Integral Cam Programmer** . . . Enables complete 1-to-24 hour program to be precast. Electric or pneumatic control on one or both pens.



**Millivoltmeter Pyrometer—Vertical Case** . . . Available in a variety of electric control forms.



**Flame Safeguard Relay** . . . Stops flow of fuel into combustion space when flame or ignition fails.



**Millivoltmeter Pyrometer—Horizontal Case** . . . Fits standard relay rack for easy mounting. Also available with dual set point.



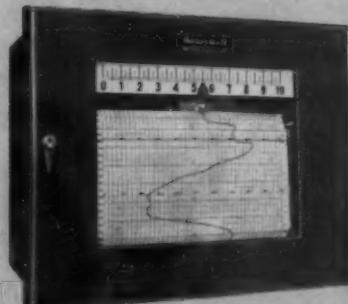
**Radiation Detector** . . . Responds to 98% of any temperature change within 2 seconds . . . high-speed model responds in half second. For applications from 200 to 7000F.



**Circular Chart Program Controller** . . . With integral cam index guide. Available with electric and pneumatic control forms.



**Heavy Duty Electric Motor** . . . For operating valves, dampers, louvers and other final control elements.



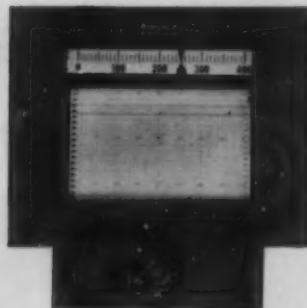
**Strip Chart Recorder**—Single or Multiple Point . . . Records all types of variables. Choice of pen speeds and chart speeds.



Precision Indicator—Circular Scale  
... Highly accurate indicator for all variables, one to 48 points.



Circular Scale Controller ... Scale is over 2½ feet long. Control index rotates with scale for 12 o'clock control check. Available in all electric control forms.



Strip Chart Program Controller ... Incorporates temperature indication, single or multiple recording, controlling—in one instrument.



shopping ...

Whether it's temperature, pressure, flow, or any other important variable you want to measure or control, Honeywell makes just the instrumentation for you. Our line of instruments is as broad as your requirements ... you can choose exactly what you need.

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MINNEAPOLIS-HONEYWELL REGULATOR Co., Industrial Division, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.



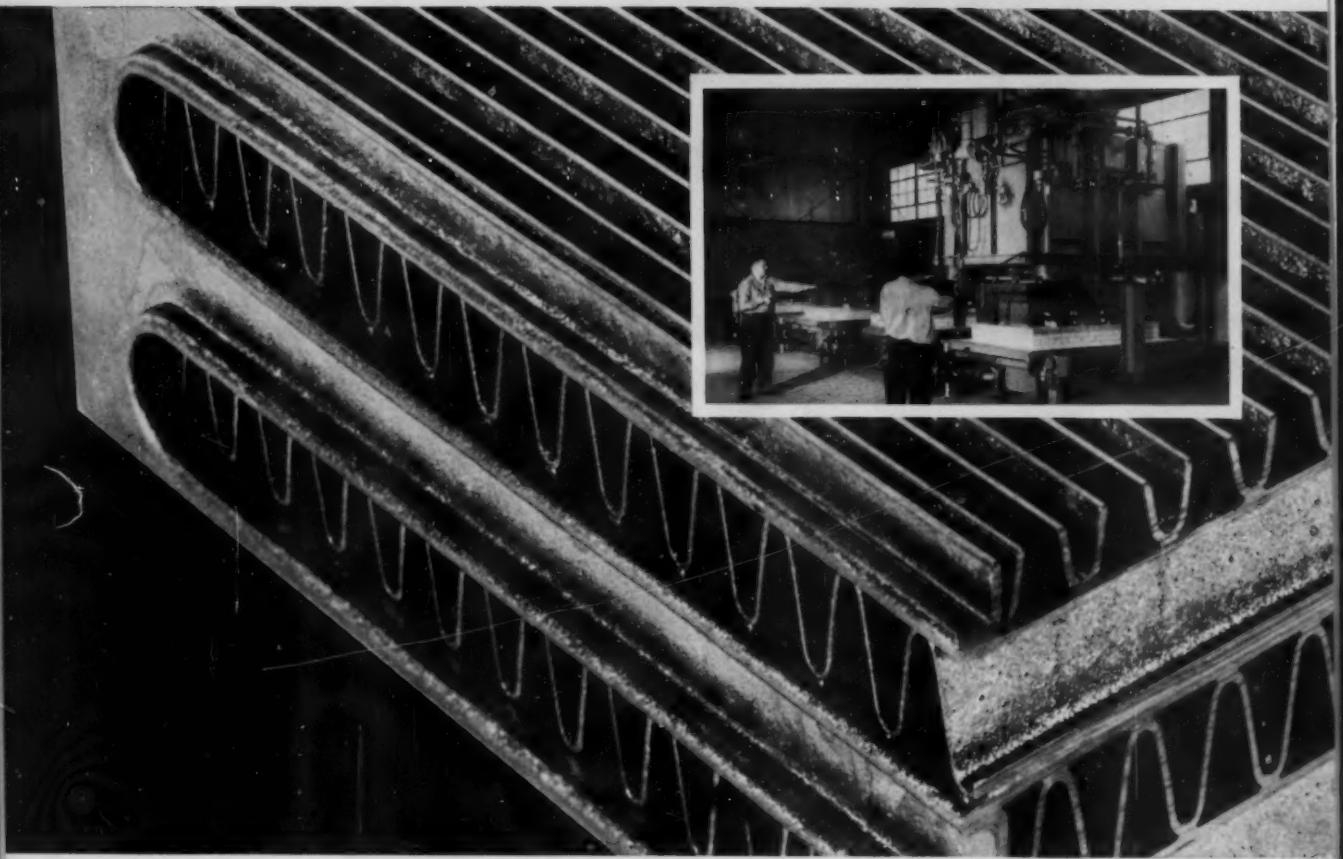
Precision Indicator—Vertical Scale  
... Has drum-type power-driven scale. Full scale travel in 12 or 4½ seconds.

# Honeywell

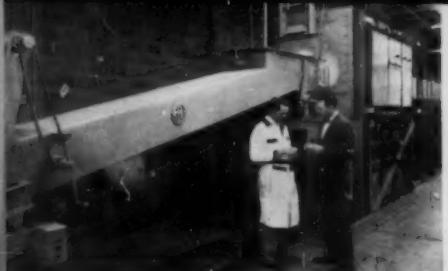


First in Controls

# General Electric engineers complex brazing problem



OTHER TOUGH BRAZING PROBLEMS SOLVED BY GENERAL ELECTRIC . . .



**CONTINUOUS BRIGHT BRAZING** of stainless-steel assemblies without flux, and bright annealing and hardening of stainless parts, make this General Electric hump-type furnace with alloy muffle a

versatile tool at Specialty Steel Treating, Inc., Van Dyke, Michigan. Hump construction of this General Electric furnace saves atmosphere gas and provides bright, oxide-free work.

**REDUCED COSTS** in assembly of 105 mm recoilless steel cartridge cases were the result of furnace brazing at Skagit Steel and Iron Works, Sedro Woolley, Washington. Use of a General Electric

## FURNACE BRAZING'S GOLDEN ANNIVERSARY

PIONEERED AND  
DEVELOPED BY G.E.



1907

A scientist in General Electric's laboratory found that, in hydrogen, molten copper wets iron and makes strong bonds.

1912

Tungsten contacts for automobile ignition systems were successfully joined to steel fingers by furnace brazing.



# help Griscom-Russell solve on Plate-Fin heat exchanger



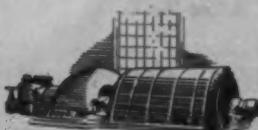
BEFORE BRAZING



AFTER BRAZING



roller hearth brazing furnace eliminates costly press work, four or more process anneals, machining and perforating of the tube after it is formed. For more information send coupon at right.



1919

Turbine-diaphragm nozzle rings were successfully copper brazed in production by G-E three-stage furnace.

## Uniform brazing achieved with new Gas-Fired Bell Furnace from General Electric

Here's a complex heat exchanger just developed by Griscom-Russell Company, Massillon, Ohio. It is constructed of mild steel, coated and furnace brazed with a nickel base alloy for high temperature gas-to-gas applications. These applications include gas turbine regenerators and furnace or kiln air preheaters for recovery of stack gas heat.

**PROPER SELECTION:** Because they needed high production capacity, rigid quality control and good operating economy, Griscom-Russell and General Electric's industrial heating specialists considered several different furnace set-ups to accomplish the braze. The solution was a gas-fired rectangular bell furnace consisting of the heating bell and four bases and retorts—for heating, holding, and cooling. This solution gives Griscom-Russell the needed effect of semi-continuous processing with the added advantage of individual heat control for each valuable load.

**PLACING THE HEAT:** To get uniform brazes throughout the work, both under- and over-firing were used. A special

piping and baffling arrangement was designed to preheat and distribute the protective atmosphere gas, dissociated ammonia. Assuring temperature uniformity and conserving heat, the new furnace exhausts are at the bases rather than through a vent at the top of the furnace.

**THEY LIKE IT:** Demonstrating that the many problems were solved satisfactorily, Griscom-Russell says, "Using the General Electric gas-fired furnace, our assemblies can be uniformly brazed and completely coated with corrosion resistant alloy in just one operation".

**THOROUGH PLANNING:** Griscom-Russell's representative goes on to say "General Electric gave us a lot of helpful advice and excellent service from early in the planning stages of the process development right through the delivery and installation of the shop-assembled furnace in our plant".

**HEAT PROCESS PROBLEMS:** Just ask for the services of your local General Electric Apparatus Salesman. Or send us the coupon for literature.

**GENERAL**  **ELECTRIC**

### FREE PROCESS BULLETINS

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General Electric Company  
Schenectady 5, New York

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- Furnace and Induction Braze, GEA-5889
- Protective Atmospheres, GEA-5907

### TECHNICAL BULLETINS

- How and Where to Use Furnace Braze, GEA-3193
- Electric Furnace Braze, GER-106
- Furnace Braze of Machine Parts, GER-339
- How to Braze Stainless Steels, GER-1331

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COMPANY.....

ADDRESS.....

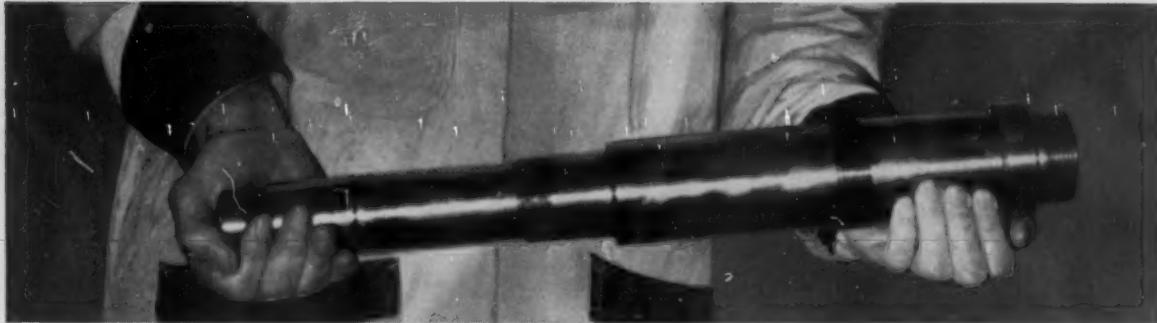
1927  
The General Electric "Monitor-top" refrigerator included several copper brazed sub assemblies.



1957

In defense, stainless steel assemblies for air frames, jet engines, guided missiles and nuclear equipment are now G-E furnace brazed to obtain high strength at high service temperatures, light weight and high quality.

# Machining Costs Cut 25% by switch to NEW RYCUT 50



## Logan Engineering Co. report shows how you can save up to 30% with a Ryerson leaded alloy

**THE PROBLEM**—This Chicago manufacturer of precision lathes faced a tough production problem from a time and cost standpoint. Lathe spindles have to be tough and hard with high wear resistance—so the steel Logan originally used was SAE 52100.

But the spindles were turned down and center-drilled from the solid to hole sizes as large as  $1\frac{1}{8}$ ". And ID's had to be accurate and free from scoring along the entire length of the spindles. 52100 provided the required mechanical properties but was slow cutting and created production difficulties and a high scrap rate.

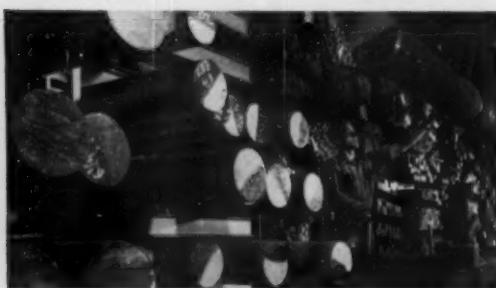
Needed: A *free-machining* steel that would develop the high hardness levels, the toughness and wear strength required for the application.

**THE SOLUTION**—Logan engineers had long been on the lookout for a steel that would solve their production problems so they were eager to try New Rycut 50 when this Ryerson 50-carbon alloy steel with a controlled lead addition was suggested by Ryerson metallurgists.

New Rycut 50 was a success from the start! Now, after two years, Harry Peterson, Logan plant superintendent, reports: "New Rycut 50 has saved us a consistent 25% of our former costs in the production of lathe spindles. Rycut's uniform machining and hardening properties have reduced scrapped parts to a minimum and the steel has proved satisfactory in every way."

This is just one of many case histories in our files on the steels in the Rycut series—New Rycut 50, Rycut 40 and Rycut 20. Actual performance records show machinability increased as much as 50% . . . tool life lengthened as much as 300% when a Rycut steel is used in place of a standard alloy of comparable mechanical properties.

To get further information on these great new cost-cutting steels or for quick shipment of any steel requirement, call or write your nearby Ryerson plant.



THESE LARGE ALLOY STOCKS . . . also carbon and stainless steels in every shape and size, are in stock at Ryerson. Also call Ryerson for reinforcing steel service, industrial plastics, machinery and tools, etc.

JOSEPH T. RYERSON & SON, INC. PLANTS AT: NEW YORK • BOSTON • WALLINGFORD, CONN. • PHILADELPHIA • CHARLOTTE • CINCINNATI  
CLEVELAND • DETROIT • PITTSBURGH • BUFFALO • CHICAGO • MILWAUKEE • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • SPOKANE • SEATTLE

## RYERSON STEEL

# Metal Progress

Volume 72, No. 1

July 1957

## Heating Methods for Modern Brazing Operations

Some observations about the brazing method (fits, assembly, cleanliness and alloys) are followed by specific information about three methods of heating for mass production: In furnaces with protective atmospheres or vacuum, in molten salt baths, and rapid heating in air by high-frequency electric currents. (K8j, K8k, K8n, 1-2)

AT A MEETING of the Industrial Heating Equipment Association held at 's 10th Western Metal Congress and Exposition in Los Angeles late in March, three papers were read on brazing — one on furnace brazing, one on salt bath brazing and one on induction brazing. Each of these papers had a good deal to say about the scope of the brazing process, the kind of parts being produced, the metallurgy of the brazed joint, and so on. Since these considerations remain much the same irrespective of the heating method which is used, the Editor has assembled this information into an introduction (mostly quoted from Mr. Webber's comprehensive paper) and then will quote from the three authors what they have to say about the merits of their respective heating methods.

### The Brazing Process

Brazing and soldering are ancient processes, and the nomenclature is sadly mixed. The old "spelter solder" is a 50-50 Cu-Zn alloy, a brass which we now call a brazing alloy. The best we can do is to adopt the definition given in the 1948 Edition of  Metals Handbook (which, by the way, includes "brazing" of aluminum assemblies):

*Brazing* — Joining metals by fusion of nonferrous alloys that have melting points above 800° F. but lower than the metals being joined.

The brazing operation is indicated in Fig. 1. The large assemblage of two tubes and two forgings comprises a part of the track for an Army tank, later to be molded in rubber. The



Fig. 1 — Examples of Brazed Machine Parts in Steel. Army tank track part consisting of two forgings and two tubes made by Burgess Norton Mfg. Co., Geneva, Ill. In-

sert shows how molten brazing metal (copper) is drawn into joint by capillarity. Small items are for business machines made by National Cash Register Co. of Dayton, Ohio

forgings are bored and the tube ends turned for a close fit, assembled, half-rings of brazing wire (copper in this instance) snapped over the tubes close up to the forging; put through a furnace with protective atmosphere at 2050° F., whereupon the copper melts and is drawn into the joint by capillarity as shown in the sketch at top. It appears at the opposite extremities of the joints as a thin copper coloring—and sometimes as fillets—giving visual indication that bonds have been obtained. Alloys with high strength are developed within the joint, a fact proven by the severe beating these parts withstand in a tank track.

Much more complex assemblages are shown in the same view. These are small mechanisms for business machines, manufactured by National Cash Register Co. These were formerly pinned or riveted—expensive manufacturing operations. They were prone to loosen up in service resulting in high maintenance costs. The assemblies are now simply pressed together and brazed into a sturdy unit, cheaper to build and maintain. Typical of such assemblies are levers with hubs, gear-and-cam clusters, brackets and segments with hubs.

Strength tests show a 52 to 287% increase

for the brazed assemblies when compared to the pinned or riveted units they replaced, which means that they can sometimes be made lighter and smaller, with less inertia and space requirements. Sometimes, more functions can be built into a given size machine or into a smaller machine. Such furnace-brazed assemblies cost 10 to 70% of the pinned ones.

**Fits and Clearances** — The closeness of fit depends on several circumstances. However, some rules can be given which will help keep one out of trouble. A common rule is that the tightest fit that can be completely filled with the molten brazing alloy will give the strongest and tightest joint; this means a clearance of about 0.002 in., but this rule may be modified if dissimilar metals are being joined. It also means that a short overlap or distance of flow can be tighter than longer overlaps. "Perfectly smooth" faying surfaces are impossible to make, and if attempted would be much too expensive. Actually, conventional finishes are not smooth; they consist of rolling country—hills and valleys—and even pressed fits will therefore have an endless network of channels through which the brazing alloy can flow by capillary action.

Optimum conditions for best strength and

Table I - A Guide for Fits

| FILLER METALS            | BASE METALS                   | FITS; IN. (ON DIAMETER)    |
|--------------------------|-------------------------------|----------------------------|
| Nickel-base alloys       | Heat resisting alloys         | 0.002 to 0.006 loose       |
| Copper                   | Low-carbon steels             | 0.000 to 0.003 press       |
|                          | High-carbon steels            | 0.001 loose to 0.002 press |
|                          | Stainless steels              | 0.000 to 0.003 loose       |
|                          | Nonferrous metals             | 0.002 to 0.006 loose       |
| Copper-phosphorus alloys | Ferrous and nonferrous metals | 0.002 to 0.005 loose       |
| Silver alloys            | Aluminum alloys               | 0.012 to 0.050 loose       |
| Aluminum-silicon alloys  |                               |                            |

tightness are not always adhered to, however, because wider tolerances are sometimes acceptable from the standpoint of service results — a joint to be merely tight against leakage, for example — and machining and assembling costs are usually lower than when optimum conditions are strived for. From experiences under a variety of conditions, Mr. Webber gives the guide in Table I, at least for furnace brazing. In dip brazing, interference fits are generally unacceptable except for copper. Usually, also, the more sluggish brassy alloys require a bit more room when brazing with induction heat.

**Assembly** — The component parts must of course be held in their proper relationship during brazing. To this end, gravity can be one's best friend or his worst enemy; it may help hold parts together or it may try to move them while they heat up and expand. Gravity may also affect the flow of filler metal into or away from the joints if it has a very loose clearance.

This brings up the dilemma: "Self-Lock or Fixture?" Usually it is preferable to design the assemblies so they self-lock. Sometimes fixtures are necessary. The decision is influenced by method of heating, position of brazing metal, and type of joint desired.

The commonest joint is the plain sleeve fit, where one part with a hole is slipped over another with a pin or shaft. The fit may be secure at the start, but when the heat is on the two may change in position if the pin is vertical. To avoid this the pin or shaft may be staked or (more expensively), machined with a supporting shoulder. The two may also be tack welded or pinned together. Peening and crimping are also done at times. A fixture may even be necessary.

If the axis is horizontal, however, movement is not so likely and such precautions are usually unnecessary.

**Cleanliness** — There must be metal-to-metal contact if the filler is to alloy with the metal on either side. This means that the contacting surfaces must be *clean*, clean of dirt and also clean of oxide. Traditionally, the surfaces were cleaned by a "flux", some combination of chemicals which would dissolve all contaminants likely to be present, and then

move away promptly ahead of the advancing flow of brazing metal. Such fluxes are still necessary when joining aluminum which oxidizes slightly in air almost instantly, but for most of the engineering metals and alloys, protective atmospheres are relied upon to keep a clean surface clean during heating and cooling.

Such a question as this remains: Must grease or oil be removed from the parts prior to assembly? It is common to remove grease, heavy oils, and soapy lubricants. Lubricants containing lead or sulphur must be removed because they affect the bond strength adversely. Some lubricants carbonize within the joints upon heating up, and inasmuch as carbon and the brazing metals have no affinity for one another, such carbon impairs strength and tightness of the bonds. Nevertheless, light oils are sometimes left on automotive and similar work where tightness is not a factor, and satisfactory results are still obtained.

Degreasing is commonly utilized but sometimes leaves questionable residues, and a good high-temperature caustic wash usually does an effective job. A good steam rinse after the caustic wash is essential; it would usually be better to leave light oil on the parts than caustic. Furnace brazing of electron tube parts and stainless steels requires immaculate cleanliness of the components — in fact, some state that "cleanliness is next to godliness".

Filler metals are available in various forms. They are sometimes placed at the joints, above the joints, or even within the joints.

Wire is used in rings, straight lengths, slugs, and hairpins. A highly recommended method for locating rings is to embed them in grooves cut in the parts during machining. Foil is used as filler metal between sheets or inserted within joints in assemblies. Powder metals are mixed to paste with liquid vehicles which are injected,

daubed, dipped or sprayed on. Powder or wire can be flame sprayed; this also may provide a protective coating on the base metal against oxidation during the heating stage. Electro-

plating is sometimes an ideal method of placing the filler metal where desired on the base metal; sometimes it can substitute for tiny rings on small components which are difficult to handle.

## Furnace Brazing

By H. M. WEBBER\*

Furnace brazing in controlled atmosphere is used particularly where uniform over-all heating enhances rather than impairs the physical properties of the part being fabricated. Brazing furnaces usually can be built for low, medium and high rates of production. Many castings, forgings and parts machined from solid stock may be redesigned and fabricated from stampings, screw-machine parts and tubing to minimize machining operations, save materials or speed production cycles, and reduce costs.

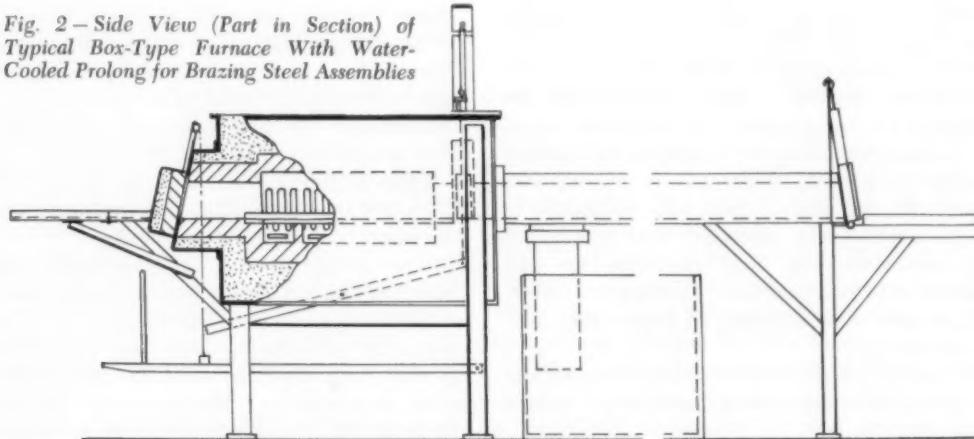
It is especially adaptable to fluxless brazing where tight bonds and immaculate cleanliness are paramount requirements. Its use of low-cost copper as filler metal on steel assemblies is often a deciding factor. Elimination of flux not only saves the fluxing material but also the cost of applying it and later cleaning off its residues. Only rarely is it necessary to use fluxes in furnace brazing.

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### Furnace Equipment

The protective atmosphere is an essential factor. Generation and control is a large topic in itself, and has been comprehensively discussed in a former meeting of the Industrial Heating Equipment Assoc. and reported in *Metal Progress*, December 1956 to April 1957. We shall therefore be content with mentioning that hydrogen gas, especially purified of oxygen and water vapor, is used for protecting stainless steel while brazing. (If a slight nitriding action and slight coloration of some alloys can be endured, dissociated ammonia, -50° F. dew point, can be substituted.) Rich exothermic gas analyzing about 15% H<sub>2</sub>, 10% CO, 5% CO<sub>2</sub>, 1.5% CH<sub>4</sub>, 3% H<sub>2</sub>O and 65% N<sub>2</sub> is the cheapest atmosphere and is quite suitable for copper brazing of low-carbon steels. It decarburizes medium and high-carbon steels, and when such articles must have hard surfaces the gas must be scrubbed free of CO<sub>2</sub> and H<sub>2</sub>O, giving a gas which is neutral to 0.40% C steels at 2050° F., the copper brazing

Fig. 2 - Side View (Part in Section) of Typical Box-Type Furnace With Water-Cooled Prolong for Brazing Steel Assemblies



temperature. For higher carbon steels enrichment with hydrocarbons, or an endothermic gas with appropriately high carbon potential, is necessary.

Furnaces electrically or gas heated of a wide variety are in use. Their essentials are that they must have a heating chamber, accurately controlled as to temperature, and so designed that infiltration of outside air must be minimized below the point where the protection of the prepared atmosphere is lost. Then the parts must be cooled in protective atmosphere (if bright work is desired, as it almost always is).

Appropriate muffle furnaces can therefore operate batch by batch, although a typical furnace for a moderate rate of production would be designed like Fig. 2, having a water-jacketed cooling chamber attached. The two end doors are normally closed to keep the gas in, and the refractory center door is normally closed to keep the heat in (except when a tray-load of work is to pass through), thus assuring longer working length and better operating economy than if it were not there. This is a most adaptable type of furnace; it is good not only for furnace brazing but for bright annealing, bright normalizing, scale-free hardening, and sintering. When gas fired, or for stainless steels when electrically heated, a metal or ceramic muffle is built into the heating chamber, or metal retorts are pushed in and out, to protect the pure atmosphere gas from being contaminated. Double doors, to serve as purging vestibules or air-locks, are generally provided at both ends of such furnaces handling stainless steels.

Furnaces for larger production are of the through type, and are considerably longer. Alloy muffles in the heating chamber are necessary when heating with gas, or when brazing stainless. Work may be carried through on traveling mesh belts. Because the hottest section of the belt is relatively weak, this type furnace is limited to handling light and medium-weight parts. Operators load work on the belt at the charging end, and either lift it off at the discharge end or dump it into tote boxes. The mesh-belt furnace appeals to manufacturers because it gives constant movement and timing of the work with no handling of trays.

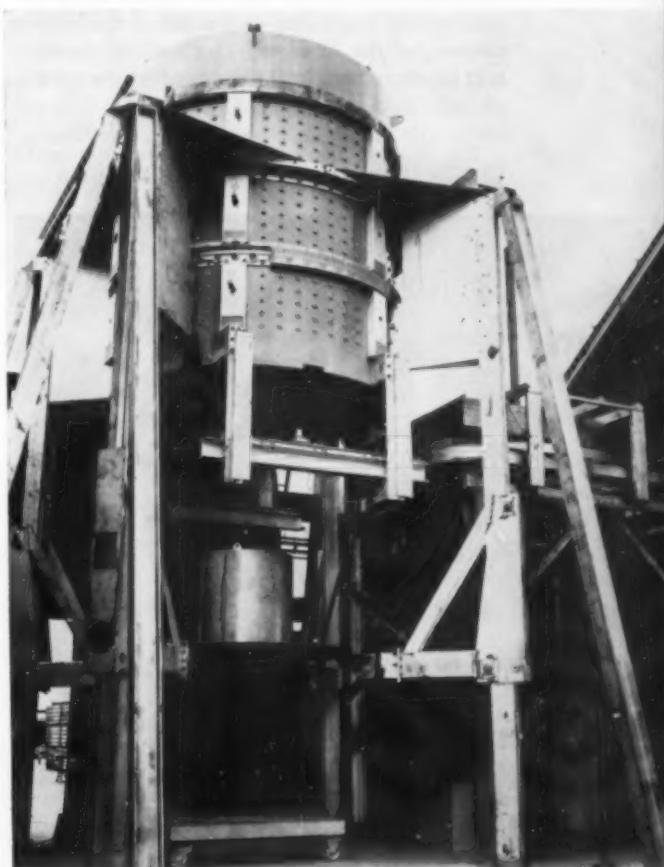
Entrance and exit doors are open just enough to clear the work, or are partly closed by flexible flaps. Gas consumption is much higher than in a closed furnace. Hence such furnaces are most useful for brazing low-carbon steel parts which by the way constitute the largest fraction of the

production, and consequently utilize the relatively inexpensive exothermic gas.

If more expensive protective gas is necessary, the "hump" furnace will serve, where the heating and cooling chambers are at an elevated level with inclined entrance and discharge sections. Such a furnace uses only one quarter to one eighth of the atmosphere gas required for a straight-through furnace, and better and more reliable results are obtained.

Through furnaces also have roller hearths, (with driven rolls) on which tray loads of work are carried through continuously. The end doors are normally closed, but the throat doors are open just enough to clear the work. This furnace is easy to maintain and is best suited for high rates of production on light, medium and heavy parts. Entrance vestibules conserve the protec-

*Fig. 3 - Elevator Type of Furnace, Where the Work is Contained in a Sealed Bell, Then Raised Into the Elevated Heating Chamber for the Proper Time-Temperature Cycle*



tive atmosphere, trays can be returned to the loading position via conveyers, and labor costs are cut to a minimum.

Bulky or heavy assemblies are commonly brazed in furnaces of the bell, elevator, car or pit type. Each has its own peculiar advantages.

Bell furnaces are familiar installations in steel mills for annealing coils of sheet or strip. They have stationary bases with permanent piping for atmosphere gas and cooling water. There is no movement or vibration of the work. Power or fuel gas can be plugged manually or automatically. But a traveling crane is required, which adds to the cost of the installation. The work is contained in sheet alloy retorts, sealed with sand or rubber rings on the bases. (Rubber-sealed retorts can be purged with vacuum pump rather than inert gas, if desired, at beginning and end of the cycle, as when brazing stainless steel articles.)

The elevator furnace shown in Fig. 3 has its own hoist that can be operated by the attendant to raise and lower cars in and out of the bottom opening of the furnace. The heating chamber is in fixed position, with power or fuel gas perma-

Fig. 4 - Setting up Klystron Power Microwave Tube for Brazing in Elevator Type of Furnace

Table II - Filler Metals Used in Step-Brazing Electronic Tubes (and Typical Furnace Temperatures Outside the Retort)

| Cu  | Ni | Au | Ag | In | Composition, % |          |         | Temperatures, °F. |          |         |
|-----|----|----|----|----|----------------|----------|---------|-------------------|----------|---------|
|     |    |    |    |    | SOLIDUS        | LIQUIDUS | FURNACE | SOLIDUS           | LIQUIDUS | FURNACE |
| 100 | —  | —  | —  | —  | 1981           | 1981     | 2050    | —                 | —        | —       |
| 62  | 3  | 35 | —  | —  | 1814           | 1868     | 1945    | —                 | —        | —       |
| 65  | —  | 35 | —  | —  | 1778           | 1841     | 1910    | —                 | —        | —       |
| —   | 18 | 82 | —  | —  | 1742           | 1742     | 1850    | —                 | —        | —       |
| 50  | —  | 50 | —  | —  | 1706           | 1742     | 1850    | —                 | —        | —       |
| 35  | —  | 60 | —  | 5  | 1580           | 1652     | 1750    | —                 | —        | —       |
| 28  | —  | —  | 72 | —  | 1436           | 1436     | 1525    | —                 | —        | —       |
| 27  | —  | —  | 63 | 10 | 1265           | 1319     | 1400    | —                 | —        | —       |

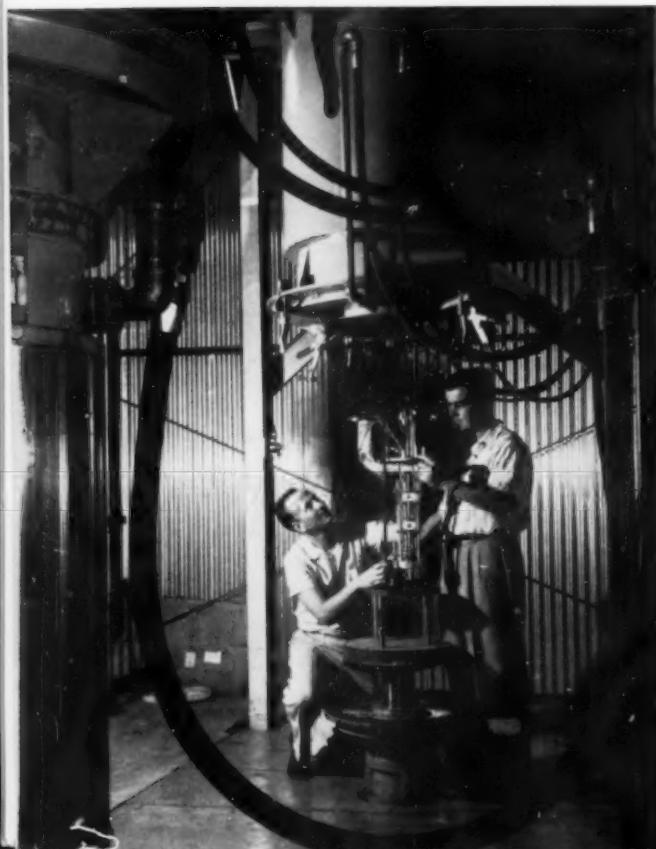
nently connected to it. Flexible connections for atmosphere gas and cooling water are attached to the bases, which are moved by hand, winch or motor drive.

#### Complex Work on Electron Tubes

Of the many examples of brazed assemblies we will describe some work which illustrates the wide adaptability of furnace brazing, namely in the manufacture of vacuum tubes, where fluxless bonds are required between metal and metal or a metal and a ceramic body.

Vacuum tightness, low vapor pressure, and immaculate cleanliness are stringent requirements commonly met. Of particular interest is the step-brazing technique used in the manufacture of klystrons or power microwave tubes, as shown in Fig. 4. Klystrons are built in a variety of designs and sizes, some up to 4 or 5 ft. high, and of a number of parts or furnace-brazed subassemblies which may consist of any of several dissimilar materials such as oxygen-free high-conductivity copper, mild steel, stainless steel, Kovar, Monel, nickel and metallized ceramics. Such assemblies are usually brazed in dry hydrogen or dissociated ammonia.

The first braze on a vacuum-tube subassembly of stainless steel or nickel is made with a filler metal of high melting point such as copper or a 3% Ni, 62% Cu, 35% Au alloy. Copper assemblies may be made with brazing alloys such as the one just mentioned or 35-65 Au-Cu. To bond a second subassembly to the first requires a more fusible filler metal than the first, and so on down the line. Selection of a filler metal for each step therefore depends not only upon its flow point or liquidus, and the temperature where a eutectic alloy may form with the base metal, but also upon its ability to wet and bond, or adversely react with the base metals involved. Gold alloys are sometimes used instead of silver alloys to



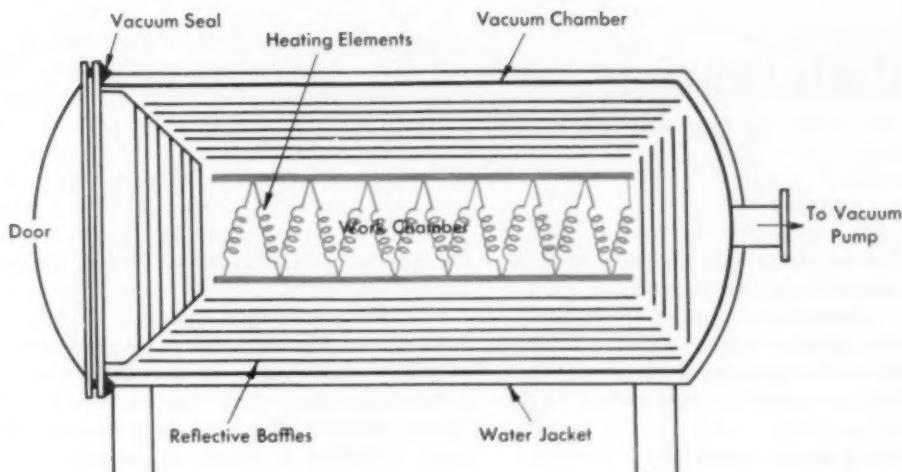


Fig. 5 – Diagrammatic Cross Section of Cold Wall Furnace for Vacuum Brazing

avoid stress-corrosion cracking of Kovar. Zinc, cadmium, lead, and other metals with low melting points are avoided because they have sufficiently high vapor pressures at the tube's operating temperatures to redeposit themselves in undesirable locations and to impair the vacuum. Typical filler metals used in step-brazing electronic tubes, and furnace temperatures therefore, are given in Table II.

#### Vacuum Brazing

Some "superalloys" cannot be brazed in dry hydrogen of the purest now available, but some can be if they are nickel plated, fluxed, or flame sprayed. Although such special procedures have merit, attention is being directed to vacuum brazing the "problem alloys" which contain strengthening additions of more than 0.5% titanium or aluminum, or both. Good results have already been obtained experimentally. The alloys containing a little titanium apparently require a much higher vacuum than the alloys strengthened principally by aluminum – on the order of 1 versus 20 microns.

Improved ductility of the bonds formed in vacuum brazing is frequently reported. Establishing the correct vacuum costs money, but the expensive protective gases are eliminated. In general, we believe that almost anything which can be brazed in dry hydrogen can be brazed better in vacuum. It seems that in the nickel-base superalloys, increases in aluminum content do not impair the brazability but increases in titanium do.

In vacuum brazing, best results are obtained when the joints can "see" the heat source since

all of the heating is done by radiation plus conduction through the metals. The furnaces themselves are of the batch type, with either "hot wall" or "cold wall" construction.

The "hot wall" furnace is generally of conventional arrangement with refractory lining supporting the heating units and backed up by insulation and enclosed in a steel casing. The work is contained in a retort which can be evacuated; it is pumped throughout the entire heating and cooling cycle. For temperatures above about 1600° F. it is necessary to "double pump" the larger furnaces – partially evacuate the heating chamber outside the retorts to protect them against collapse from atmospheric pressure. This requires special construction for strength and vacuum tightness of terminals, thermocouple outlets, and retort-to-furnace seals.

The "cold wall" vacuum furnace, Fig. 5, consists of an outer water-cooled, vacuum-tight chamber built to withstand atmospheric pressure. Within this shell are bundles of thin, reflective, metallic radiation shields, inside of which are the heating units supported on suitable insulators. Thus, the work load is surrounded by the heating units and shields, and heat is radiated directly to the work. Temperature control and uniformity are improved and problems relating to retort maintenance and tightness are eliminated.

In conclusion it may be said that the furnace brazing process is a modern production method which has taken its place among established fabricating methods and is constantly expanding its sphere of usefulness. It is able to make a wide variety of high-quality assemblies at low cost.

# Salt Bath Brazing

By L. B. ROSSAU\*

Salt bath brazing, or dip brazing (as it is commonly called) joins several components together by conventional operations with small modifications. Heating equipment is a salt bath furnace. It can handle most of the metals and brazing alloys in common use, as shown in Table III below.

The following characteristics largely determine the success or failure of the operation:

1. While the molten salt completely protects the hot surfaces from attack by oxygen or air, existing oxides cannot be reduced and therefore a flux must generally be provided. Sometimes this can be the bath itself.

2. Time for heating is one-quarter that required in a furnace. On the plus side, this enables the metallurgist to use high-zinc alloys which may lose some of the zinc in long heating. On the minus side, this sometimes melts the braze before the surface is hot enough to be wetted, so the brazing material should usually be inside the assembly or located in grooves or recesses.

3. Buoyancy reduces the apparent weight of the parts, thus reducing distortion. However fixturing must be more secure.

4. Selective heating of one end of an assembly is possible.

5. Subsequent cleaning of salt is essential, but the fluxes are cleanly removed by the salt bath.

6. The work should not trap salt, as in blind holes.

7. Dip brazing can readily be put in the pro-

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duction line with baths for hardening, carburizing and quenching.

8. Work must be clean and dry.

**Aluminum Brazing** — The rapid developments in the electronic aircraft and guided missile industries have, within the past two years, greatly increased the use of dip brazing especially as related to aluminum assemblies. We will therefore use this general type of application for examples.

The materials which, to date, have been successfully dip brazed are shown in Table IV.

Step No. 1 in the routine involves deburring all mating edges. Burrs can seriously interfere



Fig. 6 — Fixture With Ten Assemblies Ready for Dip Brazing

Table III — Range of Utility of Dip Brazing

| METAL ASSEMBLIES       | BRAZING MATERIAL                          | BATH                       | TEMPERATURE      |
|------------------------|---|----------------------------|------------------|
| Aluminum alloys        | Aluminum-silicon alloys                   | Fluxing                    | 1100 to 1150° F. |
| Copper                 | Self-fluxing alloys containing phosphorus | —                          | 1500 to 1600     |
| Ferrous and nonferrous | Silver solders                            | —                          | 1250 to 1850     |
| Ferrous                | Brass or bronze                           | Self-fluxing, with cyanide | 1675 to 1750     |
| Ferrous                | Copper                                    | —                          | 2050             |
| Ferrous                | Nickel-containing                         | —                          | 1800 to 2200     |

with the capillary action which draws the braze into the joints.

Step No. 2 is precleaning — generally degreasing in a vapor unit followed by washing in a proper detergent. Often an acid dip (nitric, or nitric hydrofluoric) for 3 to 5 min., followed by a wash and a hot rinse, will complete the operation. On occasion, machined surfaces may be etched by dipping in hot caustic solution for 30 sec., followed by an acid neutralizer, a wash and a hot rinse.

Step No. 3 is grouping the parts into assemblies and holding them together in fixtures. Figure 6 is typical of this work, which of course is infinitely variable. In the example chosen, ten assemblies are held down firmly by spring clips so the necessary tolerances will be maintained in all following steps. Sometimes larger assemblies are tack welded together; others by spinning or expanding one component into the other as for example, tube ends into tube sheets for heat exchangers.

Step No. 4 is preheating and drying in some type of oven, usually of the recirculating air type. The temperature is controlled at approximately 1000° F. This temperature is not critical.

Step No. 5 is dip brazing.

The brazing materials are usually alloys of aluminum and silicon with a flow point in the neighborhood of 1080° F. Since the melting point of pure aluminum is about 1220° F., it is obvious that the furnace temperature must be very closely controlled to avoid damage through excessive distortion or even melting of the work. With suitable controls,  $\pm 5^\circ$  F. throughout the working volume of the furnace is easily obtained and can be bettered in a well-designed electrode-type salt bath furnace.

Since the salt has a composition similar to the fluxes normally used for either torch brazing or atmosphere brazing, and is highly corrosive, the furnace is almost always heated by immersed electrodes and equipped with a ceramic pot. The operating temperature, between 1100° and 1150° F., depends on the brazing alloy and the thickness of the material being joined. Figure 7 shows a typical installation.

Table IV — Aluminum Alloys Suitable for Dip Brazing

| OLD DESIGNATION    | NEW DESIGNATION |
|--------------------|-----------------|
| Wrought alloys     |                 |
| 2S                 | 2002            |
| 3S                 | 3003            |
| 52S                | 5052            |
| 54S                | 5152            |
| 61S                | 6061            |
| 62S                | 6062            |
| 63S                | 6063            |
| 66S                | 6066            |
| Casting alloys     |                 |
| A 612              |                 |
| C 612              |                 |
| 40E                |                 |
| X 2219             |                 |
| Brazing sheets     |                 |
| 11, 12, 21, 22, 23 |                 |

Since temperature distribution and uniformity in a salt bath are not affected by the use or the position of a cover, a charge may be loaded in and out at any time desired.

Step No. 6, the final one, is to wash, rinse and dry the completed units.

**Innovations** — A rather recent development broadens the scope of applications of dip brazing for aluminum assemblies. This consists of the use of a powdered solder-flux mixture, handy and economical to apply. In some

instances it has permitted assemblies to be made heretofore impractical. This powder is mixed with water to a slurry which can be readily brushed on. After drying in the 1000° preheat, it firmly adheres to the aluminum surfaces and

Fig. 7 — Typical Dip Brazing Installation for Aluminum. Preheat oven is on right (not shown), control panels on left



does not release the brazing alloy until heated above its melting point. Considerable labor is saved in assembly and after two years of production use, it has been demonstrated that the strength, soundness and corrosion resistance of such brazed joints are at least equal to the ones made with the more conventional wire, strip or cladding materials.

The dip brazing process is also well suited to some special problems in the airframe industry, particularly in the manufacture of honeycomb structures with 17-7 PH type of stainless steels. A brazing alloy with a melting point in the neighborhood of 1775° F. is generally used. The assembly is sealed in a tight envelope so the salt is never in contact with the part and serves only as a heat transfer medium.

The time cycle need only be that necessary

to accomplish the brazing or the solution treatment, if the two operations are combined. The production capacity is, therefore, considerable. This rapid rate of heating, the short time the charge remains in the bath, and accurate temperatures permit the use of brazing alloys not otherwise practical and minimize the tendency of the alloy to run. Vertical loading of panels appears practical.

**Conclusion** — The dip brazing process is not new, but its commercial application is more recent than some competitive processes. Like all methods, it has limitations as well as advantages. Its selection, therefore, must be based on a careful evaluation of many factors. It has clearly been demonstrated to be a practical and economical procedure. It will not do all jobs, but it will do some jobs exceedingly well.

## Induction Brazing

By WM. E. BENNINGHOFF\*

When considering a heating method and its application for surface hardening or brazing, one may well ask the question, "Why heat the whole piece?" Rapid, localized inductive heating, accurately and where desired, is economical in many ways, even though it is admitted that it costs more to heat a given volume of metal with electricity than with gas or other types of fuel. However, higher production, improved quality and many other economies throw the balance in favor of induction heating. No other method can exceed the reproducibility of results of this process — whether there are a dozen parts involved or a million. Further, ready adaptability of tooling permits the handling of a wide variety of parts on a single machine. The result is that nearly half of the induction heaters now in use by American metalworking industry are used for brazing and soldering, even though these operations consume a relatively small fraction of the total electrical power devoted to induction heat treatment.

For the purposes of this brief presentation we must assume that the principles and operation of heating metals by induced high-frequency

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currents are generally understood (although in fact this is unfortunately not true). Also we will limit the examples to the joining of steel and other iron alloys with brazing alloys melting within the temperature range of 1000 to 2000° F. (although the process is also adaptable to soldering at quite moderate temperatures).

**Power** — Brazing usually requires deep heating. We generally introduce power of the order of 2 kw. per sq.in. of the area to be heated on  $\frac{1}{2}$ -in. stock, 1 kw. per sq.in. on 1-in. stock and 0.5 kw. per sq.in. on 2-in. stock. Modifications of these figures depend upon uniformity of cross section, shape, frequency of current, and similar factors. Higher power density can be used with lower frequency and vice versa.

**Cleanliness** has already been mentioned as the prerequisite of prime importance. This means no scale at the surfaces accepting the molten braze. Here is one of the best recommendations of induction heating — its speed practically prevents the formation of scale during the heating process. Therefore, a clean joint will stay clean when heated inductively.

Correct application of high-frequency energy involves an intelligent combination of frequency, power density and inductor design. Ideally,

all surfaces to be joined should arrive at the correct temperature simultaneously and after a very short heating time. Rarely can this be accomplished because of variations in mass throughout the assembly, and occasionally because of different heat transfer rates when two widely different metals are to be joined—for example, copper to steel.

The induction coil should be designed so as to introduce into the various sections of the joint an amount of heat in direct proportion to its needs. With minor variations in mass this is not difficult. Where large sections and small are involved it is easier to heat inductively the heavy mass and allow the lighter sections to come up to temperature by conduction.

A relatively uniform heat pattern is essential for proper flow of the joining alloy. To assure this, in addition to using the best coil design, the heating cycle should be long enough to eliminate excessive temperature differentials. Additional time must be allowed for the alloy to fuse and fill the joint area.

The actual temperature required is of course dictated by the alloy used, which in turn depends on the application. In general they are the silver alloys and the copper alloys, the latter giving somewhat stronger joints when a higher brazing temperature is used—silver alloys at 1000 to 1400° F., and copper alloys or copper at around 2000° F.

**Design Economies**—Much might be said about proper design of the various parts to be assembled into a unit for definite services, but these matters would not be unique to the induction heating process. Obviously the aim is to produce an article or mechanical part in a manner which will save material, machine time, and—most important—labor, as well as reduce rejects. In most instances this means the replacement of castings, forgings, or articles machined from rather bulky stock by assemblages of stampings, tubing, cold drawn rounds or extrusions.

For example, small gears, which normally would be keyed or pinned to the shaft, may be brazed at the proper position. Figure 8 is another example. It shows a flange or thrust-face collar used on a balancer shaft. In this instance a bearing area is to be prepared adjacent to the collar as well as a bearing surface on the thrust face of the collar. Conventional methods of processing would include machining from an upset forging or from a large-diameter solid bar, followed by carburizing and harden-

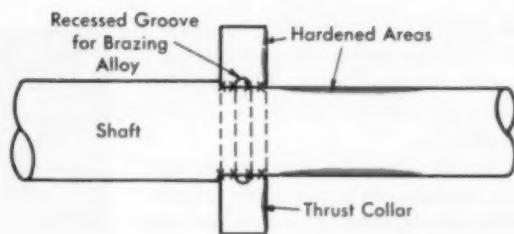


Fig. 8—Example of Job Where Brazing and Selective Hardening Are Done Simultaneously on Collared Shaft

ing. Induction heating permitted an economical change; the shaft is made from a bar with one end slightly reduced on which is assembled a collar with brazing alloy in an internal groove. This assembly is then placed in a high-frequency inductor block and in one heating and quenching cycle the collar is brazed to the shaft and the thrust face of the collar and the shaft bearing area adjacent are hardened.

**Specific Examples**—From a wide variety of specific examples space permits only one or two citations.

First should be mentioned the application which is doubtless the earliest and now leads the pack—namely brazing carbide tips to cutting tools. Countless numbers of machine shops have induction machinery, and I know of no supplier of carbide-tipped tools who uses any other method. Many have completely automatic installations. This is a "natural" for complicated tools such as milling cutters and broaches, but even such a simple thing as carbide tipping of lathe tools is done by induction at the rate of 85 per hour where former production was 80 per day with the same operator. Cost per tool was reduced from 58¢ to 4¢!

Tools are also salvaged. The same machines can be used for salvage—a broken tip is removed and replaced, or a good tip removed from a damaged tool and re-used. Another interesting salvage operation relates to stub ends of high speed tools. Consider a 1 × 1 × 8-in. lathe tool being ground and reground until it becomes about 4 in. long and too short to grip. Instead of discarding this short stub, a new tool is made by brazing it to the end of a 4-in. shank of inexpensive steel. Such an operation can justify the cost of a toolroom induction heater which is used but a few hours a day. For example, one manufacturer found that the salvaged tool cost him 46¢ (of which 6¢ is the cost of the brazing) as contrasted to a new tool cost of \$17.00. Even

for such a "nonproduction" application, savings amounted to \$2000 per month and the 15-kw., 10,000-cycle machine paid for itself in a few months.

Another example is of a brazed part which could be made in no other way except by a complicated set of machining and heat treating operations and large percentages of rejections from warpage. This is a push rod for a diesel engine valve. Several sizes are made, ranging from 13 to 18 in. long and  $\frac{1}{2}$  in. diameter. At mid-length is a collar with hardened flange. At one end is a nitrided cup and a nitrided ball on the other. The rod itself is of cold tubing. The "bull-it-through" method was to machine, carburize and nitride the entire part, which involved much expensive machining and many rejects from warpage of the long, spindly part.

In the redesign the three attachments — flanged collar, cup and ball — were each separately heat treated to appropriate hardness. Their attachment to the tube was a challenge to the fixture designers since they had to be prevented from softening during the 1275° F. brazing operation. Figure 9 shows the 30-kw., 10-ke., two-station machine for brazing the parts together, four in each operation. At the right is the four-position fixture for silver brazing the ball to the lower end. The induction coils have auxiliary devices to keep the hardened ends from softening — the bottom locator is water cooled and floods the seat. At the left is the four-position station for brazing the flange. A water-cooled felt wick is kept in contact with the hardened flange during the heating cycle.

I can only list a number of other interesting operations made by induction brazing by reason of one or more of its outstanding advantages: (a) fast, clean and economical; (b) free from distortion; (c) uniform product; (d) low rejects; (e) higher production, and (f) seeming impossibility of doing it any other way.

1. Assembling refrigerator compressor housings at 580 per hr.

2. Sealing a can of ham in 4 sec.

3. Attaching drain flange to automobile oil pans at a saving of \$6.00 per hr.

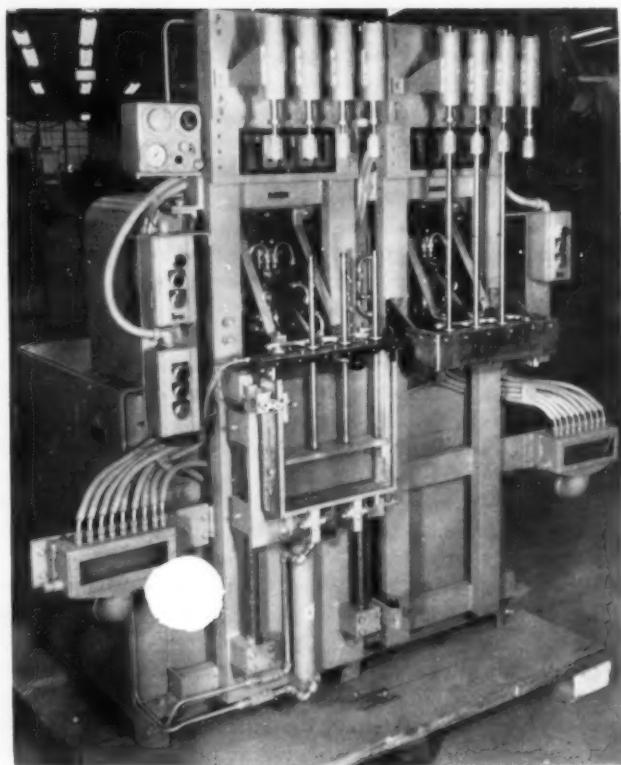


Fig. 9 — Two-Station Machine for Assembling Push Rods (Four at a Time) for Diesel Engines. In machine at right a nitrided ball is attached to the lower end. In machine at left a hardened collar is attached to the center of the rod

4. Eliminating scrap loss in assembling jet engine compressor and increasing production tenfold. One plant has 20 10-kw. units for this application.

5. Brazing yokes to tubing for power transmission shaft at a production increase of 400% and decreased cost of 67%.

6. Brazing cigarette lighters at 3600 per hr.

The many units, often quite complicated, which are being assembled today by induction brazing illustrate the surprising versatility of the process. With labor costs at their highest levels and willingness to work at perhaps the lowest in the history of our mass-production manufacturing industry, the only chance for a return to lower prices will be through the adoption of processes and techniques which will reduce man-hour and material costs per unit. Productivity — not just production — must be increased. Induction brazing and soldering is such a process!

# Book Review . . .

## A Stimulus to Zirconium Research

Reviewed by KENNETH M. GOLDMAN\*

THE METALLURGY OF ZIRCONIUM, edited by Benjamin Lustman and Frank Kerze, Jr., McGraw-Hill Book Co., New York, 1955. 776 p. \$10.00.

THIS BOOK is the most comprehensive work on zirconium available today. Its objective is to present a critical evaluation of the various facets of zirconium technology. To accomplish this, the authors and editors have carefully separated work of questionable validity—because of certain composition or processing history—from that of proven value.

Very often the value of a technical book can be judged by its usefulness to persons in a number of unrelated occupations. In this book, the student, teacher, research worker, and practical metallurgist each will find interesting and useful information, because the subject matter covers topics ranging from the refining of zirconium ore to current applications of zirconium in nuclear reactors. Research workers will be fascinated with the numerous data representing preliminary studies in the metal. Suggestions relating to future research abound in the book and should satisfy the appetite of the most prolific research laboratory.

The chapters dealing with the production of zirconium by such established processes as the van Arkel-de Boer (crystal bar) process and the Kroll (sponge) process as well as those dealing with proven melting and fabrication techniques should be very valuable to industrial people interested in working with zirconium. The comprehensive coverage of physical and mechanical metallurgy and corrosion indicates the utility of this book for everyone interested in the metallurgy of zirconium. Analytical problems related to zirconium have always assumed a role of major importance in its development. The unsung

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hero of many metallurgical investigations, the analytical chemist, will find interesting and practical information relating to various methods of analyses of zirconium and the problems associated with their use.

In the past 8 years zirconium has become one of the key materials in the nuclear power industry. Its first large-scale application was in the land-based prototype of the reactor that has powered the Nautilus for the past 2½ years. The continued use of zirconium in reactors is a clear indication of its applicability. In addition, it has other uses, particularly as structural material in the chemical processing industries. The book includes the most advanced methods in commercial use today to fabricate new products, such as tube and sheet.

The book has an interesting origin. Its writing was instigated by Admiral H. G. Rickover, who felt that there was a definite need for a book to encourage fundamental research on the metallurgy of zirconium and to arouse interest in applied research in order to stimulate its commercial development. Admiral Rickover was not only responsible for the decision to use zirconium in the submarine thermal reactor but was also the driving force for the unparalleled metallurgical development of zirconium, which was climaxed in the successful operation of the Nautilus.

It is also interesting to note that more than 50 authors, each a specialist in his own field, contributed to this book. Experts from a number of industries, universities, government agencies and laboratories are contributors.

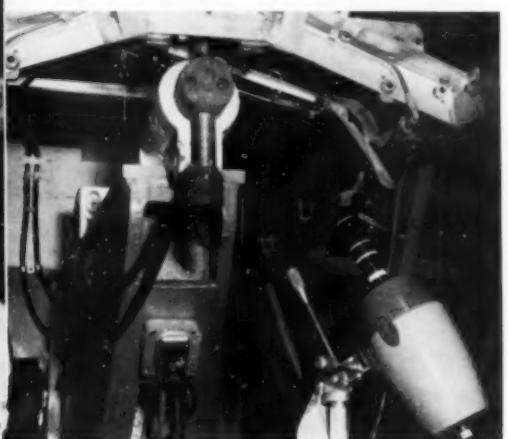
The metallurgy of zirconium is approximately 2 years old. Admittedly, some of the material in the book is now subject to a certain amount of revision as a result of new developments in zirconium technology. There certainly have been advances in alloy development since the book was written, including materials with improved physical properties and corrosion resistance. For the most part, however, basic production and melting and fabricating methods are still essentially the same. This book remains the most comprehensive source of information on zirconium available today.



*Welding Machine Operator Sees Both Bottom and Top*



*Human Inspector Watching Underside of Seam*



*TV Camera Replaces Human Inspector*

# Industry's New Silent Partner— Industrial TV

By DON POST\*

An industrial TV camera, broadcasting through a coaxial cable to a 17-in. receiver, reports more accurately and efficiently on the state of a process than the human being it replaces. (S general, X15p; Al, 7-1)

STRUCTURAL SPOT WELDING requires careful control to assure high quality. At Ryan Aeronautical Co. spot welding is frequently used to clad pure aluminum to a harder alloy core. Copper alloy welding tips are used. Because of the necessary heat and pressure, the copper tips have a tendency to pick up aluminum from the "clad". For quality control reasons it is important that this pickup be kept to a minimum. Both welding electrodes must be cleaned when the deposit appears.

An experienced operator welding a small work-piece can easily and quickly see when both the top and bottom electrode tips become sticky. However, if a large panel is being welded, which must be handled mechanically, his view of the welds is limited to the top side of the clad sheet. Another pair of eyes is needed to report on the spot welds on the underside.

This setup has long been a source of irritation, particularly to the operator's assistant who sits in a cramped, stiff-necked position throughout the operation. To correct this, three possible devices were considered — prisms, mirrors, and closed-circuit television.

The first two were ruled out because of inaccuracy and poor definition. TV provided the answer. With accuracy and clarity the television camera provides an instantaneous, magnified report of the condition of the down-under welds to a 17-in. screen at the side of the operator.

The unit operates through a coaxial cable extending from the camera to the receiver, and not through air as in commercial TV. For this

\*Assistant Supervisor of Methods Engineering, Ryan Aeronautical Co., San Diego, Calif.

reason it is not subject to atmospheric interference that sometimes plagues the home set. No aerials are required.

The set is a compact, simplified version of the commercial unit. The camera picks up the image and transmits it to the receiver. One problem involved lighting of the spot welds. Aluminum is shiny and gives a troublesome reflection. However, a combination of fluorescent and incandescent lights was found to give a clear and detailed image.

Longitudinal and crosswise movements of the panels are no problem, since automatic panning of the camera is controlled remotely by the operator. The camera follows with ease the movement of the welding seam in any direction. A closeup lens provides a magnified view of the work, and a wide angle lens scans the work and gives an over-all picture of the operation.

The set is not expensive to use since it operates at around 400 w. Maintenance is on a contract basis with immediate replacement guaranteed. The unit has operated easily and well for a number of months. The equipment, consisting of camera, amplifier, and a receiver with a resolution of 350 to 400 lines, is portable and costs around \$1500.

The unit not only frees a skilled worker for another job, but improves quality by showing clad pickup the instant it starts, on an enlarged 5-in. spot weld on the TV screen. Its use has opened up a number of new possibilities for instantly and accurately reporting production conditions often in inaccessible areas, or in dangerous places where a camera is less vulnerable than a man.

# Metallurgists Needed Badly!

## TO THE READERS OF METAL PROGRESS:

The green paper insert at the right is addressed to young students. This white paper is addressed to members of the American Society for Metals, to adult metallurgists.

We've got competition from the other branches of engineering and science — plenty of it.

If we're going to get our share of the talented youth, every single one of us has got to accept our quota — secure one recruit to our ranks.

Our individual job, each one of us, is to find one bright promising youngster outside our immediate family and work on him.

We must respect the right of each boy to choose his own field, so if we can't enlist the one of our choice, we must keep on looking until we find another.

Once we have found a protege, we must keep in touch with him; take him on an excursion now and then to a mill, a laboratory, a foundry, an assembly line, and keep his interest alive.

Report your activities to the educational committee of your local  chapter and arrange matters so that all the interested boys be entertained by the chapter once a year.

By all means, *get a move on!* Take out the green paper insert immediately and go hunt up that boy or girl.

Maybe it would help to forecast some of the logical first steps to be taken soon after the insert has been given to the high schooler (and an eighth-grader is none too young).

See him in about a week and chat with him long enough to be sure he has read the text. Clear up any questions he may ask. Go around with a second copy so if the first one has been lost, strayed or stolen the two of you can go over it together.

By all means show the youngster that you like your own metallurgical work immensely, and that equal satisfactions are in store for him.

Suggest that he talk the matter over with his school counsellor or his science teacher — making sure you talk with them first so they know what's going on.

Find out what aspect of metallurgy or application of metals has caught his interest and try to rig up some way he can come in personal contact with this particular matter.

\* \* \*

Let me elaborate a bit on the psychology behind this. I have found very few professional men who think creatively about the broad problems of a professional nature (as distinct from business, technical or scientific matters). The individuals often lack confidence in their ability to handle such matters. They're reticent because the basic techniques of personal relationships and the social sciences were not studied in college, and most of us are victims of the delusion that if it wasn't learned in the classroom, then we don't know much of anything about it! Add to this personal reticence of the average American professional man his experience of working in committees, from which he has concluded that the range of talents go from high to low; nevertheless only a low percentage of the committee-men do anything and hence there is a very low result as measured in useful work.

What this amounts to is that the average American engineer looks upon group activities by engineering organizations as using up a lot of time and energy without proportionate results.

But let me point out most emphatically that here is one thing — getting one boy or girl interested in a career in metallurgical science or engineering — where *each man is on his own*. Success or failure depends solely on his own self. This is something that you, Mr. , can do!

One taste of success and each man will be more willing to tackle another job. The misfires do limited damage, but the percentage of misfires will be quite small. You young and active metallurgists should be especially effective — don't underestimate your appeal as a guy who might have been a big brother to the high school youngster!

HORACE H. BLISS  
Oklahoma Science Service, Extension Div.  
University of Oklahoma  
Norman, Okla.

# Metallurgists Needed Badly!

Take this insert out and give it to some bright boy  
who is still in high school or who has just graduated.

Also try to sell him on your profession.

**V**ISUALIZE THE WORLD without metal and what strange, primitive conditions you would see! No tall buildings, no running water, no electricity, no automobiles, no refrigerators, no airplanes. Even simple frying pans and ordinary table knives would be unknown. We would be back in the Stone Age!

Most of the devices that make our lives easier, more convenient, more comfortable, are possible only because innumerable men we will group together as "metallurgists" have learned how to use the 65 different metals which Nature has endowed us with. Metallurgists have learned that the reason why they can make metals perform so many different tasks is that each metal has different characteristics — hence, different uses. Then, too, combinations of metals by alloying increase the variety of possibilities to an infinite number, whose limits have nowhere near been approached.

Pure iron, for example, is relatively soft and weak. Thus, no automobile manufacturer would ever use it for a gear or an axle because it would wear out quickly and not be strong enough. Instead he selects steel, which is iron (a metal) alloyed with a small quantity of carbon (a non-metal) plus a small amount of other metals such as manganese, nickel, chromium or molybdenum. Such steels can be hardened by heat treatment; they are then strong and wear resistant and will endure rugged service for a long time.

Copper, on the other hand, has no great strength but it offers low resistance to electrical currents; consequently it will be first choice for electrical wiring. Airplane manufacturers prefer strong aluminum alloys for fuselage bodies because of their light weight. Certain heavy metals such as radium and uranium are radioactive and hence unstable; the radioactivity can

be used in medicine for curing disease or for scientific research; the instability is the basis of atomic power.

Today, thanks to modern metallurgy, the metals industry can tailor metals to fit many specific needs as they arise. This wasn't always true. While men have used a few metals for a long time as weapons, cooking utensils, and ornamentation, for thousands of years they were limited to the simple metals they found on the earth's surface. They could use them for just a few of their needs. It undoubtedly took centuries of experiment to discover ways of reducing the surface ores to metal and good methods of refining them of impurities. By now we have not only mastered the purification of many of the 65 metals, but have learned to combine them into useful alloys.

Of course the job by no means is finished. That's why metallurgists are needed badly!

A whole new world lies ahead of us in the atomic age. While many think of physics and physicists when they think of atomic energy, the best metallurgical skill of our country was necessary to purify the metals going into reactors, to construct the separation plants and to shape the explosive metals which were separated. Look into the future, when most of our power will come from atomic reactors. Yet, as Norman Hilberry, director of Argonne National Laboratory of the U.S. Atomic Energy Commission, has said, "It's only a 'paper' reactor until the metallurgist tells us whether it can be built and from what."

## What Is a Metallurgist?

The need to determine which metal suits a job or how to combine and fabricate metals to achieve certain results has created a new science

known as "metallurgy", and a new set of engineers known as "metallurgists" or "metallurgical engineers". To take the guesswork out of metal manufacturing, industry employs these experts.

They have a wide variety of jobs and titles. Their common characteristic is that they supervise some work on metals, study the processes or inspect the products, sell metals or furnaces or supplies needed in their fabrication. These men comprise the metallurgical profession. Today at least 50,000 of them are employed in the United States. (No less than 28,000 are members of a single engineering organization, the American Society for Metals.)

Yet because the field of metallurgy is not a familiar one to high school students, only 670 of the 31,000 young men graduating in engineering this year have specialized in metallurgy. Such a supply nowhere meets the demand. Consequently there are good salaries and many opportunities for advancement open to such graduates.

**Fifty Years Ago** — Metallurgical engineering as a distinct profession is relatively new; 50 years ago men educated as mining engineers usually supervised the work of getting metals from ores. Their work is still necessary (as proven by extensive work now going on in the "Iron Ranges" of Wisconsin and Minnesota to learn how to make blast furnace feed out of country rock) and is now called "extractive" metallurgy. This consists of concentrating low-grade ores, smelting of ore, concentrates or scrap into crude metal and its refining into commercial purity. Another important branch of the profession, somewhat more recent, concerns itself with the production of mill shapes such as sheet, tubing, plates, rails, bars, wire. In this field the metallurgical specialist works closely with the mechanical engineer.

Beyond these tasks of producing metals ready for the metal-consuming industries we must now consider at least three other branches of the metallurgical profession, all very important indeed: (a) fabrication metallurgy, (b) research and teaching, and (c) metallurgy of atomic power and weapons. Thus the metallurgical student can plan his college work to fit him for any one of five branches of modern metallurgy.

**Fabrication Metallurgy** — The general industrial use of specialists in the field of metals engineering had its first real impetus early in World War I — 40 years ago. It was suddenly necessary for all sorts of plants which had been fabricating tools, utensils and machinery to turn

out guns, ammunition, armor, and all kinds of ordnance. Many items required the use of alloy steel, precisely controlled heat treatment, and close inspection. All of this was beyond the experience of the American metal-consuming industries of that era, whose production was based on the use of shapes of unalloyed steels or simple alloys secured from the mill or foundry, already possessing the proper hardness, strength, toughness or other property.

World War I, therefore, started a revolution in metal fabrication methods. It is still under way. It has required an army of educated men who are capable of selecting the correct metallic materials, of planning their most economical fabrication routines, of supervising their heat treatments for strength and toughness, and the final surface treatments for size and appearance.

These fabrication metallurgists, by far the largest group of metallurgical engineers at the present time, are found in foundries, forge shops, stamping plants, welding departments and fabrication operations in all metal-using industries, ranging from those making electron tubes to huge electric generators, from scooters to automobiles, from diesel locomotives to aircraft, from jewelry and cutlery to steam shovels, from fountain pens to business machines.

**Research and Development** (to which might well be linked teaching) — These men are frequently called "physical metallurgists" because their training emphasizes the physics and chemistry of metals, the two sciences being closely geared together. Physical metallurgists have come into prime importance in the last 30 years, ever since it became evident that the fabrication metallurgist needs some scientific principles to correlate his "practical" findings, and that industry has an insatiable appetite for new alloys and specialized treatments which the physical metallurgist might discover. Every large unit or segment of the American metal-consuming industry now has a well-equipped laboratory organization to which are submitted problems of "applied metallurgy". Hardly a university teaching engineering but has a research division intently studying problems in "fundamental metallurgy". Examples of the former would be a new process for a tough and machinable cast iron, or a manufacturing method for pressing and sintering metallic powders into accurate, wear resistant machine parts. An example of research in fundamental metallurgy is to analyze atomic rearrangements during a rapid quench so that a heat treatment could

be devised to produce a harder, tougher steel.

Certainly the metallurgist in the laboratory must utilize the most advanced types of investigative apparatus. He examines the metallic grains under a high-power microscope; he probes into the atomic architecture with X-rays; he analyzes for trace impurities with spectrographs or Geiger counters; he determines the mechanical and physical properties; he studies the resistance of metals to ordinary corrosion or high heat; he must draw upon the specialized knowledge of scientists in many other fields. Leaders in such work almost always have enjoyed postgraduate training and have a Master's or a Doctor's degree.

**Teaching** — Men with post-graduate and plant training also have another most important and satisfying field also open to them — teaching. A recent survey by General Electric Co. showed that about 65 Ph.D.'s in metallurgy are being graduated each year, yet in the summer of 1955 there were 55 existing vacancies in the metallurgical faculties of American universities!

**Atomic Metallurgy** — The "old" metals, such as iron and copper on which our industrial civilization is founded, are ten or eleven in number. They are relatively widely spread over the earth's surface, and are comparatively easily reduced from their ores. This leaves about 55 rarer or "new" metals which are much more difficult to come by. The properties of a few of them are only recently becoming known — for example, germanium is used for tiny transistors which are now replacing vacuum tubes. Of extraordinary importance are the elements heavier than lead, which are all radioactive. Radium was the one earliest discovered; the most potent is uranium — the heaviest natural element — and plutonium, a man-made metal even heavier. Large numbers of metallurgical scientists and engineers — literally thousands — are employed by the U.S. Defense Department in devising atomic weapons and missile systems to use these explosive metals, and by the Atomic Energy Commission and the electrical and public service industries to design and construct machinery for generating heat and power from them. These devices operate at such extremes of temperature, pressure and corrosive environment that the resources of the most intelligent metals engineers are taxed to the utmost. Progress is certainly limited by present frontiers of metallurgy more than of any other science or art. Here is an unparalleled opportunity for young men of ability.

Metallurgists also handle other types of positions. Some specialize in technical writing and editing or patent work. Others work in metal sales and service, marketing and purchasing. Managers and administrators in the metal industries are among the highest paid of our businessmen. Some companies employ metallurgists who design plants, machines and other equipment. A few metallurgists, as consulting engineers, sell their services and information to various firms — many of them small — which do not employ full-time specialists.

#### Preparation and Qualifications

Before deciding to enter the field, the prospective metallurgist of high school age should survey himself to see if he has the necessary aptitudes and qualifications. He will need the ability to undergo a long course of training which does not stop when he gets his college degree.

It begins even before entering college. The future metallurgist should take high school courses in sciences — geometry, algebra, chemistry and physics. In addition, he ought to have a definite interest in metals and their utilization in American industry. Especially if he is interested in things basic to all industry — electricity, transportation, ordnance — the business of making and using metals for tools or equipment or machinery or structures — then he should set his sights on metallurgical engineering!

It will take him four years in college to earn a degree of Bachelor of Science in metallurgical engineering. Necessary courses here include higher mathematics, physics and mechanics; advanced chemistry; English; economics; and all available courses in metallurgy.

If he decides to continue into graduate school he will specialize in some branch of metallurgy and will begin to have a part in metallurgical research.

#### Opportunities

As will be evident from the description above, almost every American industry offers opportunities to the newly trained metallurgist. He will find openings in all kinds of plants making iron and steel. Nonferrous metal industries (such as aluminum, magnesium, copper, zinc, titanium) also offer fine opportunities for employment. Machinery and all transportation equipment industries need metallurgists. Federal agencies also use them, as do nonprofit research establishments which have metal-

urgical divisions. Many university teaching positions are open to metallurgical engineers who hold advanced degrees. Jobs for metallurgists are obtainable in every state in the Union.

Although only a few women have entered the field to date, a high percentage of them have been outstandingly successful. Many desirable places are open to them especially in research and control.

Today the new metallurgist has no difficulty in finding a job. Every member of the 1957 graduating class had his choice of several attractive offers. Lists of openings in the Civil Service are available from the various government agencies. Engineering and technical societies, such as the American Society for Metals, the American Foundrymen's Society, maintain placement bureaus — as do also the college alumni associations.

**Starting Salaries** — A recent survey of the American Society for Metals showed that the wage offered in the spring of 1957 for graduate metallurgists after a four-year course leading to a bachelor's degree ranged from \$400 to \$475 per month. Those who have masters' or doctors' degrees in metallurgical engineering are offered \$100 to \$200 more.

#### Advancement

The young metallurgist on graduation will probably work in the laboratory or in an operating department until he has found his place in the world of metals. Many progressive firms insist that he take intensive courses of training (at company expense) in appropriate specialties. Then promotion will lead him up the engineering ladder. With ability and the right breaks, he may in time become chief metallurgical engineer. Or he may get into planning, administrative, or executive work in the industry.

Progress in any organization obviously depends upon the man's own ability to grow into wider responsibilities. A survey recently made by the American Society for Metals showed that, on the average, salaries progress steadily with time of service for the first 15 years after

#### For Additional Information

American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

American Institute of Mining, Metallurgical and Petroleum Engineers, 29 W. 39th St., New York 18, N.Y.

Engineers' Joint Council, 29 W. 39th St., New York 18, N.Y.

Society for the Promotion of Engineering Education, University of Pittsburgh, Pittsburgh 13, Pa.

graduation. Figures from the U.S. Bureau of Labor Statistics indicate that salaries paid to metallurgists are about 10% higher — on the average — than those paid to engineers in other categories.

#### Metallurgy in the Future

It can confidently be said that the future of metallurgy (and the opportunities for intelligent men), its expansion in the fields already occupied and its progress into wholly new ones are almost without limit. Consider the situation 50 years ago: We were in a world of steel and cast iron and simple copper alloys such as brass and bronze. In this short half-century the automobile has brought alloy steels, sheet steels and revolutionary finishing methods. Telephone, radio, television and radar have brought magnetic materials, transistors, superconductors, and electron emitters. The airplane has brought strong aluminum alloys, magnesium alloys, titanium alloys. The atomic age has fulfilled the alchemist's dream — we transform one metal into another and are using metals such as zirconium, beryllium and thorium, never before produced except as curiosities. The production of plastics and synthetic fibers depends upon metal equipment of highest strength and corrosion resistance. The farmer has vastly improved tractors and labor-saving equipment for his fields and dairies. The businessman depends on complex machines made of metal for accounting and correspondence. The housewife has a thousand helpful servants made of metal to take the place of the vanished maid.

Every man-made thing you see, every man-made thing you use, depends upon metallurgy — the intelligent application of tools, modern metals and economical fabrication.

Can anyone believe this progress will stop?

Even now, designs are made for high-speed flight a hundred miles high at thousands of miles an hour, even for earth satellites and space travel, but until the metallurgist can make materials which can withstand the severe conditions undoubtedly to be encountered, these designs will not become a reality.

National Council of State Board of Engineering Examiners, Drawer 1404, Columbia, S.C.

National Science Teachers' Assoc., 1201 16th Street, N.W., Washington, D.C.

#### For Further Reference

"Your Career in Metallurgical Engineering," American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

Pamphlet elaborating the topics briefly discussed herein, and containing a list of American and Canadian colleges and universities which give degrees in metallurgy.

# Bigger and Better Bombs\*

THE FIRST Hiroshima bomb is believed to have contained between 10 and 20 kg. of fissionable material, only 1 kg. of which contributed its energy. The inefficient use is because the atom bomb has to contain more than the "critical mass" of material before it will go off, while the amount which actually explodes is determined by the time it takes for the explosion to push the atoms away from each other so far there is no chance that a neutron will strike them.

The volume of the critical mass has been reduced by compressing a subcritical mass of plutonium into a critical size by an explosion of conventional TNT. An increase of density of 15% halves the amount of material needed for an explosion. The critical mass has been further reduced by using the isotope uranium-233 rather than plutonium as an explosive.

At the other end of the scale are the really large hydrogen "H-bombs". These have an explosive power more than 100 times greater than ordinary A-bombs. After the Bikini explosion it became clear that even H-bombs should derive the larger fraction of their explosive energy from nuclear fission rather than from fusion of the heavy isotopes of hydrogen.

In fact, the thermonuclear fusion detonates the main part of the bomb, consisting of a casing of natural uranium or of the U<sup>238</sup> residue after a diffusion plant has separated most of the U<sup>235</sup> isotope. This conclusion comes from a report in one of the scientific journals in 1955 which tells how two new artificial elements were discovered in the debris of this explosion in circumstances which imply that large amounts of U<sup>238</sup> were present.

Other than in unprecedented power, the first Bikini explosion was a cumbersome device, using refrigerated deuterium (H<sub>2</sub> or heavy hydrogen separated from water) and tritium (H<sub>3</sub>, a manufactured isotope). The first Russian H-bomb, exploded nine months later, was much more portable. Air surveys then discovered the isotope Li<sup>6</sup> in the debris, which implied that the Russians had chosen to manufacture their tritium (H<sup>3</sup>) in the bomb itself. (The impact of a neutron with a Li<sup>6</sup> nucleus results in the formation of an atom of H<sup>3</sup> and one of He<sup>4</sup>, which plays no part in bomb explosions.)

The first American application of this principle came in March 1954; the violence of the explosion surprised even its originators because they could not predict the effectiveness of really fast neutrons (such as those which come from tritium and deuterium) in fissioning ordinary

uranium. Even a year later at the Geneva conference, only a theoretical estimate was available.

At present this calculation can be made more accurately. In a bomb designed to deliver 10 megatons of energy from the outer cladding of ordinary uranium, the thermonuclear detonating explosion (H-bomb) must generate 1.0 or 1.5 megatons of energy. This detonator in turn has to be set off by a fission bomb (A-bomb) which would, in the circumstances, be 100% efficient and might therefore contribute half a megaton of energy. Altogether such a bomb would release as much energy as the burning of 2,000,000 tons of coal.

Such a bomb releases into the atmosphere 500 kg. of highly radioactive elements derived from the fissioning of the U<sup>238</sup> casing. Even after decaying one week to about 1% of their original strength, these fission products have the radioactivity of 13 million tons of radium.

But these are dirty bombs. What are the chances of making clean ones? There is some evidence that one of the two American bombs exploded in the Pacific in 1956 was of this type. The design should present no difficulties in principle, for it is only necessary to substitute some other heavy element — bismuth, ideally — for the uranium in the casing which, in a Bikini bomb, is responsible for holding the parts of the bomb together for a millionth of a second or so — long enough for an efficient explosion.

The trouble is that the heavy casing should furnish a major fraction of the energy and uranium is almost certain to be the cheapest source of this explosion energy. Lithium-6 is likely to cost at least \$125 per lb. — possibly three times as much — compared with \$12 to \$18 for uranium, and lithium yields only half as much energy as uranium, pound for pound. This is why interest now appears to have turned to cheaper ways of getting thermonuclear explosive energy and the latest Russian explosion, when it can be fully understood, may point the way.

As for the current British tests at Christmas Island in the South Pacific, there is no reason to suppose that the Atomic Energy Authority is able to make "clean" bombs, and every reason to suppose that they will be of the Bikini type. This means that their explosive power will range upwards from five megatons — say 1,000,000 tons of coal each.

\*Extracts, by permission, from article in *Manchester Guardian Weekly* for May 2, 1957, signed by "Our Scientific Correspondent".

# Titanium Tubing

By THOMAS M. KREBS\*

Seamless titanium tubing is available in a wide range of sizes in A-40, A-55 or A-70 grades with extruded and ground or machined surfaces or cold finished. Welded and cold finished tubing is also available. Alloy tubing may be obtained in the extruded and heat treated condition. The outstanding resistance of titanium to many chemicals, such as chlorides, indicates a large future use in the chemical and process industries. (F24, F26, T general; Ti, 4-10)

**T**IATIUM TUBING, of a sort, was available as long ago as 1950. In an article in *Iron Age* for April 6, 1950, A.M. Bounds described the manufacture and properties of relatively small-diameter tubing made by inert-gas shielded-arc welding of rolled strip. This was made of commercially pure metal; the welded tube was subsequently cold drawn to size. Seamless tubing was also available then in very limited quantities and was obtained by cold drawing drilled bar stock—a costly process.

In early 1952, shortly after Babcock & Wilcox had installed the Ugine-Sejournet process using glass for lubrication, one of the titanium producers asked us to extrude and cold work a small quantity of titanium tubing. This first trial was encouraging and other small orders followed. This tubing was surface ground after extruding.

Long experience with carbon and high-alloy steel proved that cold finishing would improve surface quality, but "commercially pure titanium" quickly fractured on the cold draw benches. This was our first experience with the detrimental effects of "interstitials" in the microstructure: The metal had been induction melted in a graphite lining and contained about 0.4% carbon. The ductility could not be improved and the tubing was scrapped. More modern methods, involving double melting under vacuum using first high-purity sponge and then a consumable

electrode, now produces a homogeneous ingot of excellent quality for the manufacture of tubing.

Experience and manufacturing skill soon increased to the point where the so-called commercially pure grades of titanium are now produced as standard items in both cold finished seamless and welded tubing over a wide size range. A notable quantity of seamless titanium alloy tubing, chiefly the 6% aluminum, 4% vanadium grade, has also been produced as extrusions, or extruded and heat treated. Cold working of titanium alloy tubing is still in the experimental stage.

## Hot Working Routine and Product

Raw stock for seamless tubing is a round billet, approximately 7 in. in diameter, which has been forged from a large ingot so as to permit maximum forging reductions with attendant homogenization and grain refinement—both having a significant bearing on optimum properties in extruded and heat treated alloy tubing. The forged stock is then turned. The scalped billets are heated for piercing in an inert gas atmosphere to prevent absorption of oxygen and nitrogen, both of which are embrittling agents. This method of rather deliberate heating and soaking has so far given us better results than the more rapid induction heating.

"Canning" of the billet with less reactive metals can be done, but this runs the risk of

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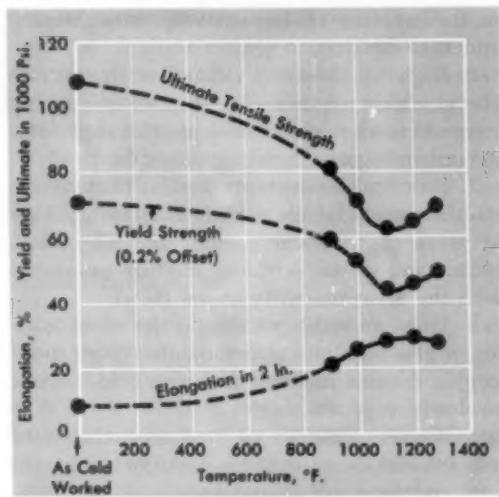


Fig. 1 - Effect of Annealing Temperature on Properties of Cold Worked A-40 Titanium Tubing (Commercially Pure Titanium With 40,000 Psi. Minimum Yield Strength)

alloying effects and involves the necessity of removing the jacketing and alloyed layers.

Piercing and extrusion are carried out at 1600 to 1700° F. for commercially pure titanium, and 1700° F. or higher for the stiffer alloys. At these temperatures the metal works comparably to austenitic stainless steel at 2100 to 2200° F.

The common tubemaking processes, particularly hot piercing, hot extrusion and cold drawing, involve heavy pressures and intimate frictional contact between the work and the die or mandrel. Because of the well-known tendency of titanium to gall and seize under frictional contact with metal, proper lubrication is mandatory. Glass is the lubricant used for hot operations. Milder deformations at lower temperatures may use more conventional lubricants, such as grease-graphite or molybdenum sulphide. However, care must be used, especially in any heating, to avoid contamination of the product from the lubricant.

At present sand-blasting is the preferred method for removing the glass lubricant or heavy scale. Considerable use has been made of a molten caustic bath at 1000° F. for cleaning, although this has involved some accidents. For example, 6Al-4V alloy tubes were severely corroded; the reaction in the bath was violent and the tubes caught fire on removal. Reaction occurred in both fresh and used baths and with both cold worked and annealed tubing.

Thin scale or discoloration resulting from heat

treating or low-temperature forming operations may be readily removed by pickling at 130° F. in 20 to 30% nitric acid containing 2% hydrofluoric acid. The nitric acid is high enough to minimize hydrogen pickup. (Titanium tubing is consistently being produced with hydrogen under 150 ppm. which is currently considered safe. Such alloy tubing will successfully withstand the notched tensile test at 70° F., which is used as a criterion of hydrogen contamination.)

After extrusion, cleaning and straightening, the tubing now corresponds to a hot finished product. Commercially pure grades of titanium tubing in the larger sizes (over 3½ and up to 6 in. OD) may be obtained as extruded products with a turned or ground outer surface and — if required — with a bored inner surface.

A significant quantity of heavy tubular sections of titanium alloy has been supplied in the as-extruded and heat treated condition for ordnance applications. Examples are 8½ in. OD by 1¼ in. wall and 6 in. OD by 1 in. wall. These are of the 6Al-4V alloy, quenched and aged to 130,000 psi. minimum yield strength.

#### Cold Working Routine and Product

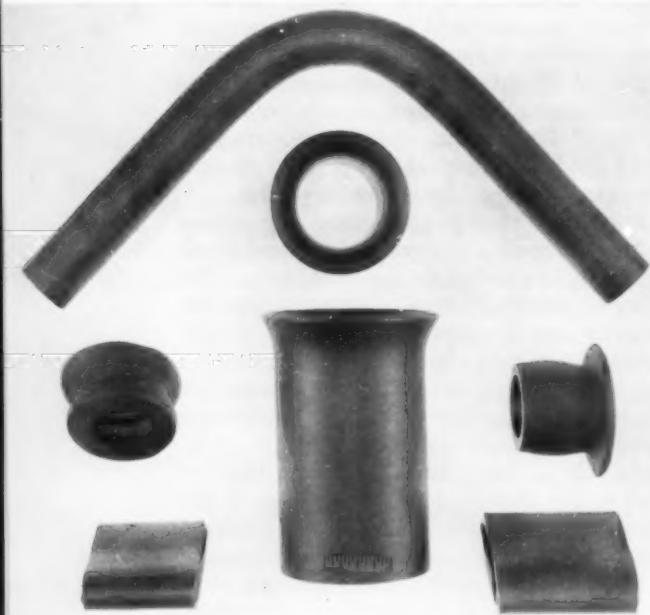
To produce economically the highest surface quality with close dimensional tolerances and to manufacture smaller sizes than can readily be extruded, seamless tubular products under 3½ in. OD are usually finished by cold working on draw benches or roto rocking machines. We now regularly cold finish the commercially pure titanium tubing having 40,000 (A-40) or 55,000 (A-55) psi. minimum yield strength and also the lean alloy or commercially pure grade having 70,000 (A-70) psi. minimum yield strength. Cold finished tubing of the higher titanium alloys cannot as yet be consistently made.

Prior to cold working operations, any surface defects are removed by grinding the outside and by boring or grinding the inside diameter. The tubes are extruded large enough to facilitate the cleaning and conditioning operations. Conditioning the outer surface is done on heavy-duty belt polishing equipment using a noncombustible oil for coolant. Experience with pyrophoric metal has demonstrated the fire hazard of inflammable oil for coolant. Workmen must be alert to the danger of sudden ignition of fine titanium dust in the tubes during grinding. Good housekeeping must also avoid any accumulation of titanium dust or fine machining chips which can ignite and which are potentially explosive.

In spite of titanium's generally poor workability, in comparison with austenitic stainless steel, manufacture or later fabrication of titanium tubing can be done on the same equipment as used for steel. Of course some modifications in procedures are necessitated by the metallurgical characteristics of titanium and its alloys. Those characteristics may be summarized as follows:

1. Hexagonal lattice structure of alpha titanium, which limits intracrystalline slip and plastic deformation as compared with austenitic stainless and aluminum.
2. Relatively high yield strengths, requiring more power in forming.
3. Lower work hardening tendency than austenitic stainless steel, which causes a less uniform response to deformation in tension.
4. Poor ductility under triaxial stressing, illustrated by lower reduction of area in the tension test and poor performance of samples containing minor defects in deformation tests which reflect lower notch ductility.
5. Low modulus of elasticity (16,000,000 psi.) coupled with relatively high yield strength is responsible for titanium's greater tendency to spring back on forming; this is of significance

*Fig. 2 – Ductility of Cold Finished A-55 Titanium Tubing Is Demonstrated by Bending, Crushing, Flaring, Flanging and Flattening*



in the welding of formed strip, straightening and tube bending.

6. High yield-tensile ratio (flat stress-strain curve) which requires close control of forming forces to work in the narrow plastic range without exceeding the breaking strength.

7. Poor heat conductivity (similar to austenitic stainless steel) which permits heat to build up at areas of frictional contact and aggravates seizing and galling – which is in turn associated with the great reactivity of the metal.

8. Titanium resists yielding under rapid loading or at a high rate of deformation (high strain rate) and consequently should be cold worked as slowly as practicable.

9. Warming the metal decreases the yield strength and increases notch ductility and toughness and increases formability.

Cold finishing of tubing is customarily done either by roto rocking or by bench drawing. In roto rocking (which is similar to the tube reducing process) the metal is rolled in compression in a reciprocating tapered-grooved die and over an indexing, tapered mandrel. This process permits a greater reduction and is less demanding from the standpoint of lubrication than the bench drawing process where the tubes are pulled through a die, with or without an internal mandrel, under tensile stress and extreme frictional conditions. Several proprietary lubricants have been used with satisfactory results and the one developed by Battelle Memorial Institute looks promising. The thin oxide coat formed during stress-relief heat treatment has antigalling characteristics and affords some protection against seizing.

The purer grades of titanium tubing, A-40 and A-55 with minimum yield of 40,000 and 55,000 psi. respectively, can be readily cold formed once the inherent properties of the metal listed above are recognized. Cold finished tubing is available in the full range of tubular sizes from about 3½ in. OD to redrawn tubing as small as 0.012 in. OD. The less ductile A-70 grade (70,000 psi. minimum yield) is also available cold finished in limited tubing sizes between 3½ and 1 in. OD.

**Annealing** – Tubing of the commercially pure grades may be annealed and ductility restored between cold forming operations or at finish by heat treatment at approximately 1200° F., as shown in Fig. 1. Annealing in air is satisfactory except for small-diameter or light-walled tubing requiring a number of anneals in process, when vacuum annealing is necessary to prevent excess

sive atmospheric contamination and loss of ductility. If slight surface contamination occurs and maximum ductility is required, the affected surface layer can be removed by polishing. If pickling is employed for this purpose, care must be exercised to prevent absorption of hydrogen.

Deformation test specimens illustrating the ductility of finished titanium tubing are shown in Fig. 2.

### Welded Tubing

From the very beginning titanium tubing has been produced by rolling and welding strip, using inert-gas shielded-arc techniques (argon or helium). Welded tubing can be cold drawn for finishing similarly to seamless. Needless to say, titanium tubing can be fabricated by processes involving welding; however, the ductility and toughness of the welds will be directly proportional to the efficiency of shielding used to prevent pick-up of interstitial elements. A trailing shield should be provided for added protection of the hot weld zone.

### Titanium Alloy Tubing

As remarked above, the cold working of titanium alloy tubing has been a mixture of successes and failures leading to a hope that the problems can be eventually solved rather than to a statement that commercial success is imminent. In some trials, the alpha-beta alloy containing 6% Al and 4% V has been successfully roto rocked to small tube sizes. (Raw material was short sections flash welded together!) The best that we can say of the all-alpha alloy containing 5% Al and 2.5% Sn is that it may have limited cold workability for tube manufacture.

The problems encountered in the cold forming of titanium alloys stem from an intensification of the same nine factors previously enumerated for the purer grades. The yield strength of the present-day substitutional alloys is two to three times higher than in the most readily cold worked grades A-40 and A-55. Ductility — especially notch ductility — is proportionally lower. As in the forming of sheet, warming to 400 to 600° F. increases the "cold" workability in tube manufacture and in later fabrication. This is typified by the curves of Fig. 3, showing short-time high-temperature tests on Rem-Cru C-130 AM alloy (4% Al, 4% Mn). Tensile strength, yield strength and the yield-tensile ratio are decreased with increasing temperature, which is favorable to forming. While the "ductility" (reduction of area and elongation in the

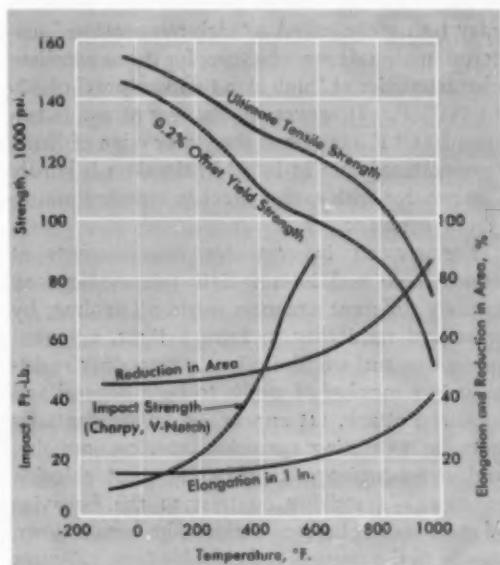
tension test) is not greatly affected by increasing temperature, the Charpy V-notch impact strength, which correlates to some extent with notch ductility, is rapidly raised as formability improves.

In general, a significant difference in the forming and use of steel and titanium alloys lies in their different response to heat treatment. Most steels can be readily softened for forming operations and then heat treated to properties suitable for service. Titanium alloys, on the other hand, retain comparatively high strength and hardness after annealing. At present this must be accepted as the norm. In any event, development of an alloy satisfactory for cold or warm working into tubing and capable of being heat treated to yield strengths of the order of 110,000 to 130,000 psi. would be a reasonable goal for the immediate future. Such an alloy should command a market for hydraulic lines, engine and structural components in high-speed aircraft.

### Utility

About 95% of the titanium mill products are sheet, forgings and extrusions for the aircraft industry. While this lack of diverse market will be detrimental in the long run, the insistent demand from the Air Forces that the material be produced and used has conferred a measure of security on the young industry and certainly

Fig. 3 — Influence of Temperature on Tensile and Impact Properties of Rem-Cru C-130 AM Alloy (4% Al, 4% Mn)



encouraged extensive research and commercial developments.

Outside the ordnance and aircraft industries, it is anticipated that the market for titanium alloy tubing for mechanical or pressure applications will be slow to develop. Hot finished alloy tubing has been available in limited sizes for some time but has not generated a significant demand from industry. Special applications may, of course, arise in the transportation industries where the weight saving would be attractive, but this is apparently of no particular advantage in many mechanical applications for tubing. Even where this is attractive, consumers will continue to weigh carefully the economic factors, machining characteristics, heat treatment and forming capabilities before selecting titanium alloy tubing over established alloy steels.

One added and extremely important characteristic, however, is the superior corrosion resistance of titanium. Insofar as tubing is concerned it seems quite probable that eventually the heaviest demand will be from the refining, chemical and process industries for handling corrosive materials — frequently at both outer and inner surfaces as in heat exchangers.

It would appear that, in general, titanium will lack the versatility of austenitic stainless steels for process service since the latter may be used either for strength or for corrosion resistance or for both at temperatures considerably above the working maximum for titanium (probably in the vicinity of 1000° F.). In this connection a word of caution should be inserted. Titanium may be rightly called a "high-temperature" material in aircraft manufacture, for it has excellent characteristics at "high skin temperatures" of 400 to 600° F. However, in many process industries 1000° F. may be at the lower edge of "high temperature", and at 1000° F. titanium is hardly competitive with carbon steel in ordinary atmospheric exposure.

For service in corrosive environments at atmospheric and intermediate temperatures an entirely different situation exists. Titanium, by reason of its ability to form a tight, adherent protective surface film offers outstanding resistance in a number of media to both general and localized attack. It appears to be substantially immune to pitting corrosion, crevice corrosion and stress-corrosion cracking in most chloride solutions — a striking contrast to the behavior of stainless steel whose surface film breaks down locally in the presence of chloride ions. Figures

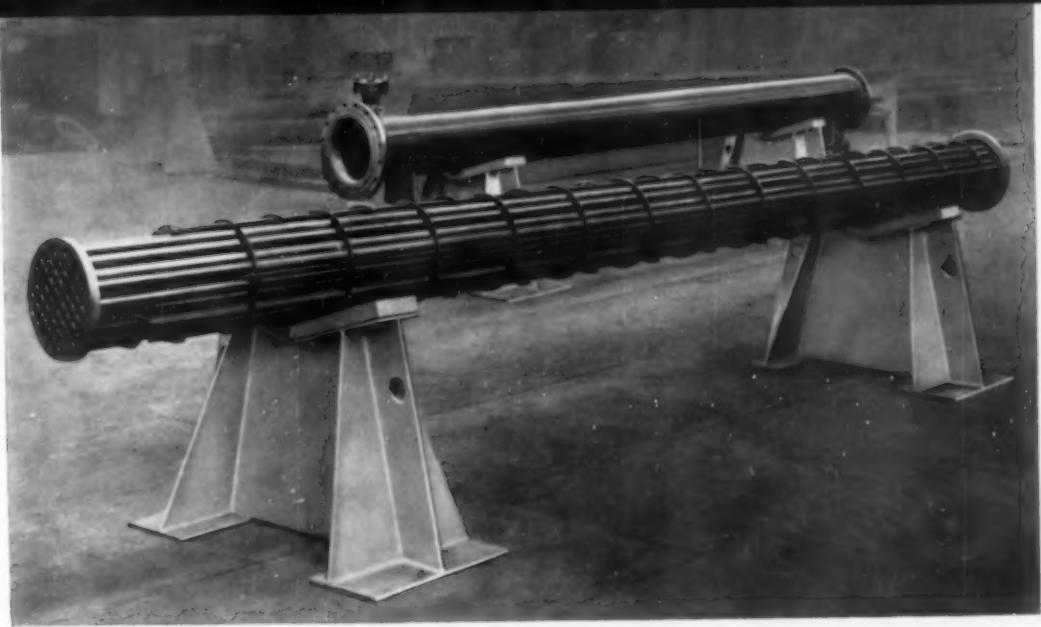
4 and 5 show the resistance to pitting and crevice attack in 10% ferric chloride for 16 hr. at 75° F. For this reason titanium is particularly promising for service in chloride environments such as sea or brackish waters, chemical or pharmaceutical manufacture, in chlorinating reactions generally, and in the handling of hot nitric acid.

It is anticipated that tubing of relatively pure titanium — that is, A-55 grade — will continue to be of primary interest because of its excellent corrosion resistance, availability over a wide size range, and its combination of useful strength, good ductility and fabricability by bending, welding, expanding, flaring and similar operations.

The heat exchanger shown in Fig. 6 demonstrates this utility. This is used in chemical plant service to cool a 15% solution of sodium hypochlorite which had proved extremely corrosive to other materials and resulted in excessive downtime. Glass tubing, while it resisted corrosion, had such poor heat conductivity that the liquid in process could not be cooled rapidly enough and the quality of the product deteriorated. These troubles are avoided with A-55 titanium tubing. The tube ends are fusion welded with filler rod to  $\frac{1}{4}$ -in. commercially

Fig. 4 — Illustrates the Resistance of Titanium to Pitting in Stagnant 10% Ferric Chloride at 75° F. as Compared with Common Stainless Steels. From left — Ti, Types 316, 304, 430





pure titanium plate, backed by carbon steel to form the tube sheets. This unit has given excellent service for more than a year and is hailed as the solution to a serious plant problem.

Such instances point up the fallacy of many arguments advanced by corrosion engineers against "high-cost titanium". While the first cost of the raw material is much higher than stainless steel, for example, the cost of the fabri-

Fig. 5 — Illustrates Resistance to Crevice Attack on Reverse Side of Test Specimens Shown in Fig. 4. Crevice resulted from contact with glass supports



Fig. 6 — Heat Exchanger Made With 48 Tubes, 1 In. by 0.075 In. A-55 Titanium, 16 Ft. Long, Giving Excellent Service in 15% Sodium Hypochlorite Solution in a Chemical Plant to Solve a Serious Corrosion Problem

cated unit, installed, may be only two or three times as great. In such instances it is apparent that wherever titanium will give two or three times the life of stainless, the saving in maintenance costs and decreased downtime — which are very significant economic factors — represent the profit on thoughtful engineering. In essence the decision to be made is no different from that faced by the engineer who changes from carbon steel to a considerably more expensive stainless to solve a corrosion problem.

In summary it can be said that commercially pure titanium tubing has become a standard production item. Seamless tubing of the A-40, A-55 and A-70 grades is available over a wide size range in the extruded and surface finished condition or in the cold finished condition. Welded and cold drawn tubing of commercially pure grade is also available. Titanium alloy tubing can be furnished in the extruded and heat treated condition corresponding to a hot finished product.

Considerable information concerning the characteristics and handling of the metal has been acquired by tubing manufacturers which will be of value to users and fabricators. Apart from aircraft, ordnance or other defense applications, titanium promises to be an outstanding material for troublesome corrosion applications involving piping or heat exchange in the chemical and process industries, particularly for handling solutions containing chlorides.

# Criteria for Evaluating Electrical Resistance Alloys

By C. DEAN STARR\*

Even though the "life" of Ni-Cr and Ni-Cr-Fe resistors, as measured by standard test, has been increased tenfold in the past 30 years, the industry is still improving the older standardized analyses, and seeking new varieties of Ni-Cr-Al, Fe-Cr-Al and molybdenum-base alloys for more severe services.  
(S21, Q general, 2-12; SGA-q.)

**M**AXIMUM EFFORTS are being made today on both a laboratory and production scale to develop new and improved alloys for use at ever-increasing temperatures. Associated efforts are directed toward the inevitable requirements for suitable equipment to anneal and heat treat such alloys successfully. One of these requirements is that furnace elements, electrical resistors, must be improved so they can operate at higher temperatures.

**Present Temperature Limitations** — At present, most electrical resistance furnaces in production sizes utilize either nickel-chromium-iron or nickel-chromium heating elements. The maximum recommended operating temperature in air for a widely used wrought Ni-Cr-Fe alloy (35% Ni, 20% Cr, 45% Fe, trade named "Tophet D") is 1800° F. while our Ni-Cr type alloy with 80% Ni and 20% Cr known as "Tophet A" and covered in A.S.T.M. specification B 82-50 is suitable for use up to 2100° F. This is the maximum temperature for dependable service of Ni-Cr heating elements at this time. For higher operating temperatures it is necessary to use either gas-fired furnaces or heating elements that have some undesirable characteristics.

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Electrical heating at elevated temperatures is preferable to gas heating for the same reasons advanced for the existing use of electrical heating elements at and below 2100° F., namely:

1. Accurate and responsive automatic temperature control is obtainable in properly designed units. Control is reliable, adaptable and simple.
2. Uniformity of temperature is readily secured by the liberation of heat at the desired positions and in the amounts needed with relatively small temperature differential between heat source and work space.
3. Resistance heating is readily applied to a wide variety of furnace types and sizes. Since such design considerations as combustion volume, flame travel and venting of waste gases do not exist, electrical furnaces are compact and convenient.

4. There are no products of combustion to be vented.
5. The amount of heat radiated to surroundings is relatively small.

These advantages can be achieved for temperatures up to 2500° F. by using either tungsten or molybdenum heating elements. Unfortunately, when exposed to hot air or atmospheres containing water vapor they form low-melting-point

Fig. 1—Equipment for Measuring the Life of Electrical Resistance Elements



oxides and sublime. This is particularly true of molybdenum. Moreover, both elements are embrittled when they become carburized. Hence, these elements can only be used under specific types of reducing atmospheres which so far have limited their commercial application to rather small production units or highly specialized laboratory equipment.

The only other wrought alloys that are being used in the temperature range from 2100 to 2460° F. are the iron-chromium-aluminum alloys shown in Table I, available commercially under various trade names. Resistor elements of this family are recommended only for oxidizing atmospheres. Their disadvantages are:

1. In small sizes they rapidly increase in hot resistance with time.
2. Exceedingly poor hot strength, which can cause premature failure by creep under such minor loads as the weight of the element itself.

Table I—Analyses of Various Commercial Fe-Cr-Al Alloys

| TRADE NAME   | FE | CR   | AL  | CO  | OTHERS    |
|--------------|----|------|-----|-----|-----------|
| Alchrome     | 79 | 15.5 | 5   |     |           |
| Kanthal A    | 68 | 23.4 | 6.2 | 1.9 | 0.06 C    |
| Kanthal D    | 71 | 22.6 | 4.5 | 2.0 | 0.09 C    |
| Smith No. 10 | 55 | 37.5 | 7.5 |     |           |
| Ferropyr I   | 86 | 7.0  | 7.0 |     | 1 (Mn+Si) |
| Megapyr II   | 65 | 30.0 | 5.0 |     |           |
| Aluchrome O  | 65 | 30.0 | 5.0 |     |           |
| Aluchrome I  | 73 | 22.0 | 5.0 |     |           |

3. They become embrittled with long use.
4. Care must be taken to avoid contact with refractories containing silica and iron oxide which cause severe oxidation of the alloy.

It must be said, however, that when these elements are properly designed, supported, and carefully used, they will give good service up to 2450° F.

For resistance heating units up to and above 2700° F., silicon carbide units (such as "Globar" and "Hot Rod") are available. Since they are brittle, susceptible to mechanical and thermal shock, and change in resistance with time and temperature (which necessitates transformers with tap-changing switches), they are usually installed in special designs not generally adaptable to wrought electrical resistance elements.

For resistance heating units up to 5400° F., carbon units are commercially available. These have the same general limitations as the silicon carbide elements, and in addition require an oxygen-free atmosphere. Consequently neither of these types of resistance elements can generally be substituted for wrought resistance elements.

There is then a rather large temperature range (2150 to 2600° F.) in which there is an urgent need for new wrought electrical resistance elements. The manufacturers of such elements are well aware of this, and are either conducting or sponsoring both basic and applied research on the development of new alloys to

meet the requirements. When they have found answers to the questions "What is life?", "How can it be measured?" and "What knowledge is required to improve it?" they will have achieved their initial goal.

**Life Tests** — At present, life is defined as the ability of a metal or alloy to withstand exposure at elevated temperatures in air under either cyclic or steady state conditions for prolonged periods of time. This complex property of an alloy is measured according to the procedure given in A.S.T.M. Specification B 76-39 by the life test equipment shown in Fig. 1. (In passing, it might be noted that the last number in the designation represents the fact that no major change has been made in this document since 1939, nearly 20 years.)

In this test a wire 0.0253 in. in diameter is cycled electrically between room temperature and some elevated test temperature (2150° F. for 80-20 Ni-Cr or 2050° for 60-15-25 Ni-Cr-Fe) so that the specimen is at temperature for 2 min. out of every 4-min. cycle. The temperature is initially measured by an optical pyrometer and the hot resistance of the sample determined from the voltage and amperage of the circuit. "Life" is then expressed as the total time in hours that is necessary to cause either a change in hot resistance of 10% or to cause failure or burnout of the sample. Subsequent field tests of units in actual industrial operation then permit a correlation between the industrial life of an alloy and its laboratory life.

This testing was introduced as a tentative standard in 1929 and clearly distinguished between the Ni-Cr and the Ni-Cr-Fe heating elements. At that time, the test temperature was specified as 1950° F. in order that the test would run between 100 and 150 hr. With increased improvements in the 80-20 Ni-Cr alloys, which resulted in a corresponding increase in their life, the test temperature was progressively increased until it now stands at 2150° F. With the exception of the test temperature, the American Society for Testing Materials test today for life is essentially unchanged from its provisions in 1929. The good correlation that has been achieved over the years attests to the validity and usefulness of this type of test for differentiating between good and poor heats of nickel-chromium type alloys. Consequently, for the nickel-chromium alloys now being made there exists a definitive laboratory test for life.

As a measure of the metallurgical achieve-

ments of 30 years, it may be said that cycling 100 hr. to 1950° F. was considered satisfactory for 80-20 Ni-Cr wire. Today 350-hr. cycling to 2150° F. is normal.

It is questionable whether this method of testing is appropriate for the Fe-Cr-Al alloys that are to be used in heavy sections as well as others yet to be developed. Consider, for example, the data in Table II obtained in a modified A.S.T.M. test wherein the maximum *temperature* in each cycle was maintained constant — approximately twice as drastic as the A.S.T.M. test when the *voltage* peak is maintained constant. Since the Ni-Cr alloy failed before its hot resistance changed 10%, the life is recorded as the hours to burnout, namely 170 hr. The life to burnout of the Fe-Cr-Al alloy was 181 hr. but a 10% increase in resistance occurred after only 70 hr. and by specification, this is the life of this alloy.

It has been suggested that the rapid increase in hot resistance of Fe-Cr-Al alloys is due to initial oxidation at high temperatures, and during the subsequent cooling portion of the cycle the strength of the oxide layer in compression is greater than the strength of the alloy in tension. Hence, the normal thermal contraction of the metal is prevented and the sample elongates. On reheating, the oxide coating, being weak in tension, cracks and the metal underneath expands normally. The new surface exposed under the cracks then oxidizes and the process continually repeats itself.

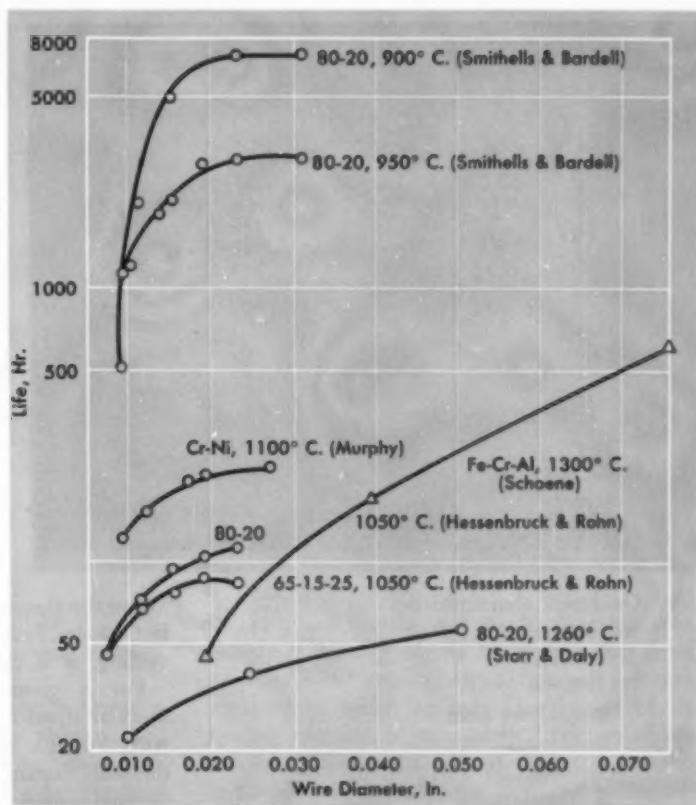
Accordingly, the change in hot resistance is primarily a mechanical manifestation of the continued decrease in the diameter of the wire attending the elongation or growth of the alloy. Data obtained by Brown in which the elongation during life testing was measured and the true diameter calculated, have confirmed the

Table II — Life Test for Tophet A and Alchrome Wire 0.0253 In. Diameter; Cycling Temperature 2150° F.

| TIME   | CHANGE IN HOT RESISTANCE |                      |
|--------|--------------------------|----------------------|
|        | 80-20 Ni-Cr              | 79.5-15.5-5 Fe-Cr-Al |
| 25 hr. | 1.9%                     | 4.3%                 |
| 50     | 3.0                      | 8.0                  |
| 75     | 3.7                      | 10.25                |
| 100    | 4.4                      | 11.6                 |
| 125    | 4.9                      | 12.4                 |
| 150    | 5.2                      | 13.6                 |
|        | (170)                    | (181)                |

Values in parenthesis refer to actual hours to burnout.

Fig. 2 - Effect of Wire Diameter on the Life of Ni-Cr and Fe-Cr-Al Alloys



postulate that the increase in hot resistance is almost entirely attributable to a decrease in specimen diameter and its increase in length.

A second confirmation is obtained by comparing the test life of larger diameter wire, which should increase appreciably since the mechanical balance between the load-carrying capacity of the core and oxide coating is shifted in favor of the core. The data in Fig. 2 relating wire diameter to life appear to confirm this hypothesis. In contrast to the minor effect of specimen diameter for Ni-Cr alloys, an increase in diameter from 0.0253 to 0.076 in. for Fe-Cr-Al alloy results in a tenfold increase in test life. Recent tests in our laboratory, as well as investigations abroad, have not been able to confirm the data for Fe-Cr-Al alloys shown in Fig. 2. But both investigations do show that the life of ferritic Fe-Cr-Al alloys increases more rapidly with diameter than the austenitic Ni-Cr alloys.

Thus, if the industrial application of Fe-Cr-Al alloys is concerned with the use of small-sized elements, the existing life test gives a representative value for the alloy. But if large-size elements are to be used, the existing test may not

be a satisfactory method of rating — particularly if the criterion is life to 10% increase in resistance. This is only one of the items under study; perhaps a change in temperature limits or in the time cycle or both will turn out to be for the better.

Finally, it might be pointed out that although Globar (silicon carbide) units operate satisfactorily at 2750° F. in industrial applications, they would not successfully pass the life test as now standardized. This, then, is why some modifications or at least interpretations are needed in existing life test procedures to rate new or existing alloys adequately.

The final question, "What knowledge is required to improve high-temperature alloys?" necessitates an evaluation of the properties of an alloy which affect its use at elevated temperatures, namely:

- I. Melting point
  - a. Original
  - b. After contamination
- II. Thermal shock and thermal stress fatigue
- III. Mechanical properties
- IV. Resistance to volatilization

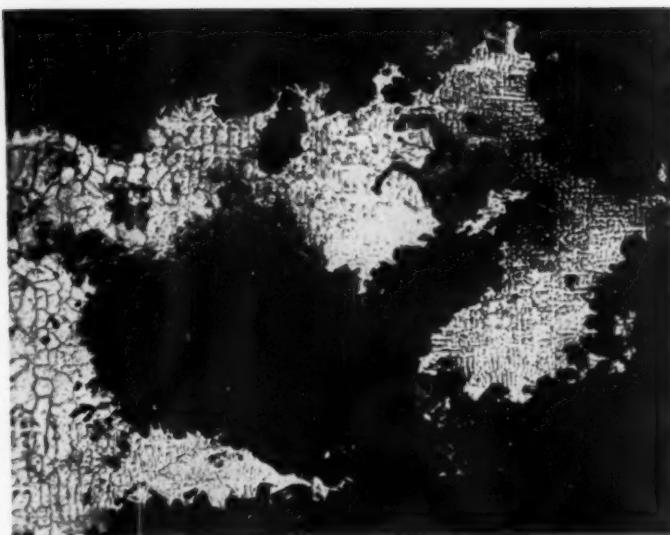


Fig. 3 - Failure in 80-20 Cr-Ni Element by Melting. Life tested at 2300° F. Etched in Marble's reagent; 100×

#### V. Oxidation characteristics

- a. Internal
- b. External
  - 1. Type
  - 2. Melting point
  - 3. Strength
  - 4. Rate
  - 5. Tenacity

**Melting point** of the metal or alloy must obviously be above the operating temperature of the resistance element. While this condition may be met initially, it may change after prolonged service because of contamination with elements such as carbon, zinc, tin, or lead which lowers the melting point of the alloy.

Consider carbon: It would be anticipated that a maximum of 2% carbon corresponding to complete change of the 20% chromium in the alloy to  $\text{Cr}_7\text{C}_3$ , could be diffused into an 80-20 Ni-Cr alloy. Experimentally, using a high carbon potential at 2100° F., values of 1.97% have been reached. This lowers the melting point from 2550 to approximately 2350° F.

Although these conditions may not be obtained in service, they are approached. Hence failures have occurred in furnaces operating at a safe temperature for uncontaminated resistance elements. A typical failure by melting is shown in Fig. 3.

**Thermal stresses** are caused by nonuniform distribution of temperature. If the thermal stress is of sufficient magnitude to exceed the rupture strength of an alloy in any given cycle, the resulting failure is labeled "thermal shock".

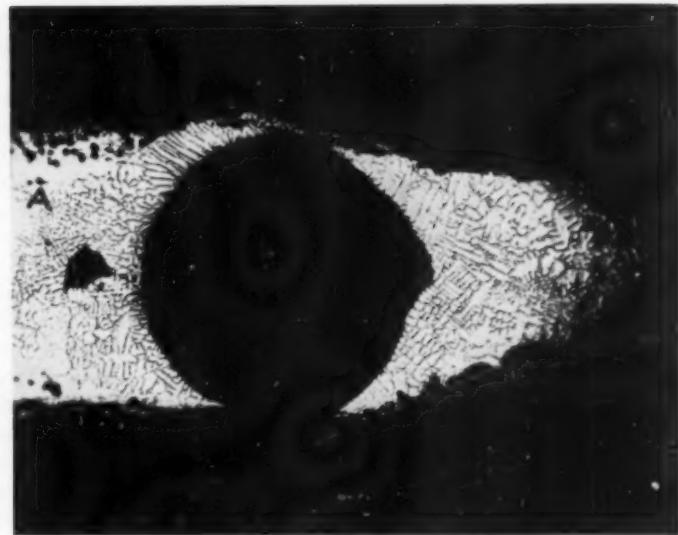
When the thermal stress is of a lower magnitude but causes failure after repeated temperature cycling, it is called "thermal stress fatigue".

For a given temperature differential, the thermal stress for a given shape varies directly with Young's modulus and the coefficient of thermal expansion, and indirectly with the thermal conductivity and (1 - Poisson's ratio).

Because resistance alloys have relatively low thermal conductivity and high coefficient of expansion (particularly the Fe-Cr-Al alloys) they are subject to thermal shock or thermal stress fatigue. For example, cast ingots of "Alchrome" (Fe-Cr-Al), if allowed to cool in air, will fracture readily from nonuniform temperature distribution in the ingot; they must be promptly stripped, reheated, and rolled. Although nickel-chromium alloys do not exhibit this tendency in the cast condition, they can fail from thermal stresses, as shown by sharp, jagged edges of life-test specimens tested at 2350° F. (A progressive failure would have resulted in extensive oxidation and rounding off of the edges.) This type of failure, which is relatively unknown in electrical resistance elements at lower operating temperatures, would also be anticipated to be a minor factor in commercial furnaces at higher temperatures - of the order of 2300° F. - because of the relatively slow rate that furnaces are heated and cooled. But such failures can be expected to occur much more frequently in cyclic laboratory life tests conducted at 2300° F. and above.

**Mechanical properties** desired in electrical resistance alloys after fabrication are:

Fig. 4 - Failed Specimen With Small Voids Near the Surface Caused by Volatilization of Chromium at 2350° F. (Large central hole is caused by melting in "hot spot" region; note the surrounding dendrites typical of cast structure.) Etched in Marble's reagent; 100×



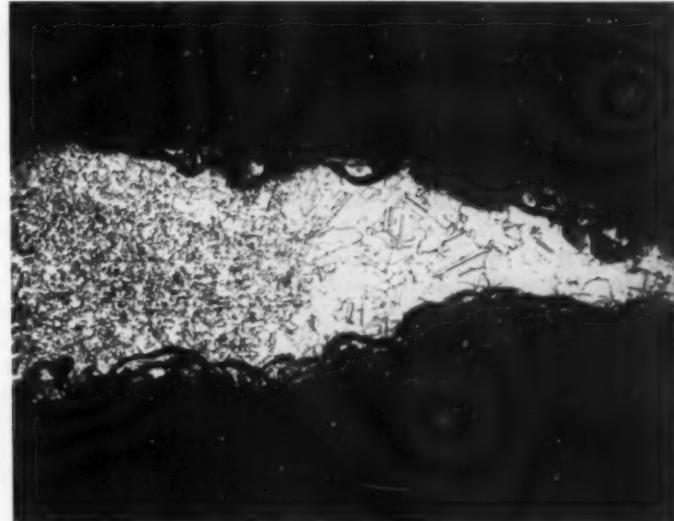
1. High creep strength above 2100° F.
2. Low modulus, to minimize thermal stresses.
3. Ductility.

High creep strength is necessary to insure a furnace element of uniform cross section. Although the only stress (aside from thermal) is the weight of the element itself, the temperature is sufficiently high to permit some creep. If this is nonuniform, a corresponding decrease in cross-sectional area occurs at particular locations along the furnace element, which in turn locally increases the resistance. For a constant voltage input, this gives a higher  $I^2R$  value at

the localized section and results in a hot spot. Failure generally occurs at such a hot spot. Failures in industrial electrical furnaces are often repaired by removing only one section of the heating element or sometimes a portion of one section. Hence the requirement for ductility in the alloy after prolonged use.

**Volatilization** - Preferential loss of elements such as chromium in Ni-Cr alloys occurs to some extent in the vicinity of 2000° F. At yet higher temperatures, the rate of volatilization naturally increases. In Fig. 4 is a sample of an 80-20 Ni-Cr alloy that failed in life testing at 2350° F.

Fig. 5 - Failure of "Tophet A" at 2200° F. Caused by Alternate Oxidation and Scaling Which Produced a Reduced Section. Etched in Marble's reagent; 100×



Numerous small voids caused by volatilization of chromium (vapor pressure 0.1 mm. Hg), as proved by the deposition of chromium on the walls of the life-test chamber, were observed along the length of the sample. Such preferential depletion of alloying additions reduces the oxidation resistance of the alloy, and it wastes away. Resulting hot spots can raise the temperature of such a locality until melting occurs. A typical example is also shown by Fig. 4, where a large hole surrounded by dendrites is left in the center of the specimen.

**Oxidation** — Minor additions of strong deoxidizers such as calcium, zirconium, and misch metal (primarily cerium) markedly improve the life of electrical resistance alloys. Whether this is due to the high degree of internal deoxidation (possibly reducing the tendency for submicroscopic oxides along the grain boundary) or whether it is caused by a decrease in the rate of diffusion of metallic ions through the oxides on the surface is not known at present. Since only minute amounts of deoxidizers are retained in the alloy, their location and distribution are difficult to detect. Vacuum melting of these alloys may permit definitive conclusions.

The literature on the external oxidation is much more voluminous; major emphasis is placed on the rate of oxidation of various alloys in air. Unfortunately, when the life of an alloy is compared with its rate of oxidation, no direct and consistent correlation exists. When adding more than 6% chromium to nickel, the rate of oxidation decreases and the life of the alloy also progressively increases. However, when silicon is added to an 80-20 Ni-Cr alloy, the rate of oxidation increases and so does its life.

Thus, the rate of oxidation, even though important, is not the sole criterion of useful life of an alloy. Other variables such as the type of oxide (whether simple oxides like  $\text{Cr}_2\text{O}_3$  or spinels such as  $\text{NiO}\text{-}\text{Cr}_2\text{O}_3$ ) and the lattice structure of the matrix must be considered. The deleterious effects of oxides with low melting points have already been noted. Perhaps the most significant aspects of oxidation in relation to life reside in the tenacity of the oxide to the matrix.

Eiselstein and Skinner have made an extensive investigation of the effect of thermal cycling on scaling of Ni-Cr and Ni-Cr-Fe alloys. Since the consecutive processes of oxidation, fissuring and spalling result in localized reduced sections, hot spots can be readily formed in this manner. Figure 5 shows a typical failure in "Tophet A",

life tested at  $2200^{\circ}\text{ F.}$ , caused by oxidation and subsequent scaling.

More recently Gulbransen and Andrews have suggested a "strain oxidation" test to evaluate the adhesion between the oxide film and the substratum, wherein the alloy is oxidized a given amount, strained in tension from 1 to 4%, and then reoxidized. The rate of oxidation immediately before and after straining can be used to classify the type of damage that has occurred. Results from this method of testing have so far shown a correlation with the standard life test; thus, the adhesion of the oxide may be the significant thing to control the life of heater alloys.

**Future Progress** — These are some of the requirements that are before the manufacturers of electrical resistors in improving the existing product and developing and evaluating new alloys. The problems are formidable but they are being met. An example already quoted is that in 1929 a life of 100 hr. at  $1950^{\circ}\text{ F.}$  was considered satisfactory, whereas at present, lives of 350 hr. at  $2150^{\circ}\text{ F.}$  are normal. Since a life of 100 hr. at  $1950^{\circ}\text{ F.}$  is approximately equivalent to a life of 30 hr. at  $2150^{\circ}\text{ F.}$ , the 80-20 Ni-Cr alloys now available have been improved over 1150% in the past 27 years. Continued research has resulted in experimental alloys with a life of about 440 hr. at  $2150^{\circ}\text{ F.}$  — a further increase in life of 25%.

This value, it appears, is approaching the limit of life for minor modifications in the simple 80-20 Ni-Cr type. Major modifications may still improve the life. Recently Ni-Cr-Al alloys have been released from the research laboratories in England for field tests at temperatures up to  $2275^{\circ}\text{ F.}$

Major improvements can be anticipated in Fe-Cr-Al alloys. In the laboratories of Wilbur B. Driver Co., experimental alloys have been made which on occasions show 100% improvement in life without objectionable growth beyond a level comparable to existing nickel-chromium alloys.

Other companies are conducting extensive tests on molybdenum-base alloys using both powder metallurgical and coating techniques. Operating temperatures as high as  $3150^{\circ}\text{ F.}$  without the requirement of special protective atmospheres are the principal objectives of these investigations.

Thus it can be anticipated that improved existing alloys as well as new alloys will permit the use of higher and higher temperatures in the years ahead.

# New Horizons in Powder Metallurgy

Reported by CORD H. SUMP\*

Production of nickel and copper powders from low-grade raw materials; compacting of powder between rolls into strip; manufacture of felts from metallic fibers; rapid sintering activated by volatile salts in the compact. (H general)

POTENTIALITY of powder metallurgy for the near future was the keynote of the 13th Annual Meeting of the Metal Powder Association held recently in Chicago. There seem to be great possibilities of improving present manufacturing techniques in the production of powders of special properties, in compacting to commercial forms such as sheet or strip, in specialized materials of high porosity and low density, and in the sintering process itself. Complete proceedings will be available later from the Association's main office at 130 West 42nd St., New York 36, N.Y.

**Powder Production** — According to R. J. Loree of Sherit Gordon Mines Ltd., Fort Saskatchewan, Alberta, Canada, nickel powder can be chemically precipitated from solution by hydrogen at 200 lb. pressure and 275° F., in the presence of nucleating agents of which ferrous sulphate is now favored. The liquid is agitated so as to suspend the nuclei while the nickel precipitates upon them. At present, the resulting powder is compacted into briquettes for stainless steel melting stock. The hydrogen content of the powder is extremely low. The use of ferrous sulphate for nucleation means that the finer powders are higher in iron content. They are described as being spherical clusters, and it was suggested that the finer powders could replace those prepared by the carbonyl process. Another interesting possibility for this process is the coating of tungsten or other hard carbide powders by

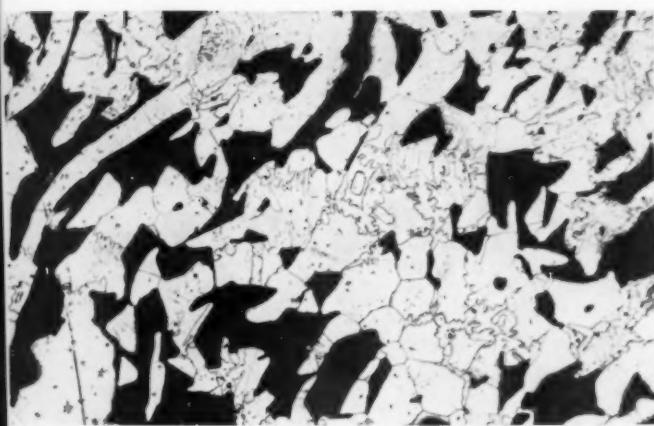
nickel or cobalt; by suspending the carbides in the precipitating vessel, each carbide particle can acquire a metallic skin completely enveloping it, and forming the most if not all of the metallic binder necessary to hold a sintered compact together.

Analogous methods were described of making copper powder from copper alloy scrap, too low in grade to be economically melted into secondary ingot. Interested readers are referred to an article on this topic by Messrs. Work, Shaw and Knopp in *Metal Progress* for October 1955.

Production of an extremely fine iron powder was announced at the meeting, but even on questioning the speaker (M. W. Freeman, M. W. Freeman Co., Detroit), no information was given on the method of preparation other than the fact that it was an electrolytic process.

Formation of unusually perfect metal crystals was given as a reason for the reported improved properties of parts made therefrom. Bearings made of these very small crystals mixed with electrolytic copper powder have given superior results when tested against steel shafts. It was also said that the crystals act almost as activated chemicals in linking together organic molecules. For example, hot pressed compacts of synthetic chemicals, like nylon or rubber, and tiny iron crystals produce a new material with high-temperature stability, toughness and wear resistance.

\*Supervisor of Powder Metallurgy Research, Armour Research Foundation, Chicago.



*Sintered Fibers of Type 343 A  
Stainless Steel. 60% density. 50 X*

**Compacting** — Rolling or roll bonding of powder into continuous strip or sheet, first described by Samuel Storchheim in *Metal Progress* last September, has been given further study by W. V. Knopp of S-K-C Research Associates, Paterson, N.J., and we were told that a commercial plant would be in operation within the next 12 months. It was found that the powder can best be gravity-fed into rolls, placed side by side with axes horizontal. Angle of nip of 7° is optimum.

A continuous process from powder to coiled sheet produces a sheet 6 in. wide and 20 to 25 mils thick. It was found that there is an optimum roll speed; at higher speeds the edges were much more dense than the center of the strip, and when speeds were too low the opposite condition resulted.

Apart from nonuniformity of the sheet, improper speeds caused folding and edge cracking. It was also found that hot rolling reduced the number of steps required for processing; 95% density was obtained after only one hot pass. However, some material is of such a nature that it must be cold rolled.

The old reliable press was not neglected. A panel of manufacturers' men\* presented the advantages of various types of commercial equipment. Single punch, single motion presses were

\*J. D. Shaw of S-K-C Research Associates was moderator. Panel members included W. Gort of Arnhold Ceramics, Inc., Dorst, N. Y.; B. B. Belden of Baldwin-Lima-Hamilton Corp., Hamilton, Ohio; J. J. Kux of Kux Machine Co., Chicago; C. C. Sutinen of Mannesmann-Meer Engineering and Construction Co., Easton, Pa.; G. G. Karian of F. J. Stokes Corp., Philadelphia; and H. E. Elliott of Watson-Stillman Press Div. of Farrel-Birmingham Co., Roselle, N.J.

contrasted with multiple punch, multiple motion presses. As metal powders do not flow readily during compaction, multiple action moves the powder at appropriate times and in desired directions or amounts during the pressing cycle. The advantages of the hydraulic press stem from such considerations as rigidity, longer die life, and maintenance of closer tolerances. Some European presses which were described appeared to be especially useful for fabricating complex or difficult shapes; one of their features is the use of a stationary lower punch and a floating die; the compact is ejected by auxiliary tooling.

**Fiber Metallurgy**, described in *Metal Progress* in March 1955, has progressed to a place where pilot plant production of sheet material by the S.O.S. Co. of Chicago could be described. C. H. Sump and W. Pollack of the Armour Research Foundation outlined the method of preparing metal sheet of sintered fiber as a continuous process. Microstructures were exhibited and gave evidence of the necessary emphasis which must be placed on the metallic bonds at fiber-to-fiber junctures in order to achieve a strong product.

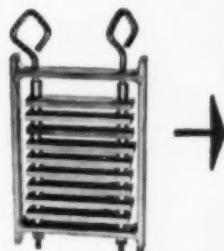
In this same connection, the use of copper to bond metal "felts" (bulk material of only 5% of theoretical density) was noted as an easy method of preparing highly porous metal that is self-supporting. The material is being processed to a wide range of densities, from a few per cent to nearly 100%. The advantage of this material is its strength even at high porosities. Fatigue strength of the sintered product is also high enough so that it should be useful for reinforcement of plastic parts which have given trouble in service from fatigue failures.

**Activated Sintering**, as performed at the plant of La Métallurgie des Poudres at Beauchamps, France, was described by M. Eudier of that organization. He stated that the wide difference in strength of powder metallurgy parts noted when testing parts from the production line could be reduced by activated sintering. He also reviewed the influences of sintering time on such properties as conductivity, tensile strength, elongation, and impact strength, saying that, in general, longer sintering time develops better engineering properties. In the French plant a highly reactive vapor is utilized to activate the physical action. For example, ammonium fluoride is added to an iron powder compact which is placed in an iron box and covered with alumina. Heating at 2050° F. for (Cont. on p. 116)

Studying the behavior of metals and alloys in elevated temperatures is facilitated by using racks of test specimens. Shown here is such a rack, installed near the hot end of a superheater in a generating station operated by the Public Service Electric and Gas Company, Newark, N. J. This rack hangs next to the seventh row of superheater tubes, in a zone in which operating temperatures up to 1475°F are reached. The test is designed to determine which alloys perform best as hangers or tube supports.



The test rack carries many specimens, all of which are of different compositions and are precisely measured and weighed before installation. Metal loss, corrosion rates and other desired information can thus be accurately determined upon conclusion of the test.



The same test rack after 648 hours' exposure shows the effects of a corrosive environment causing deposits that included up to 36% vanadium pentoxide (V<sub>2</sub>O<sub>5</sub>) and 32% sulfur compounds. The boiler in which this rack was exposed was fired with Bunker "C" oil from Venezuela... a high sulfur content fuel.



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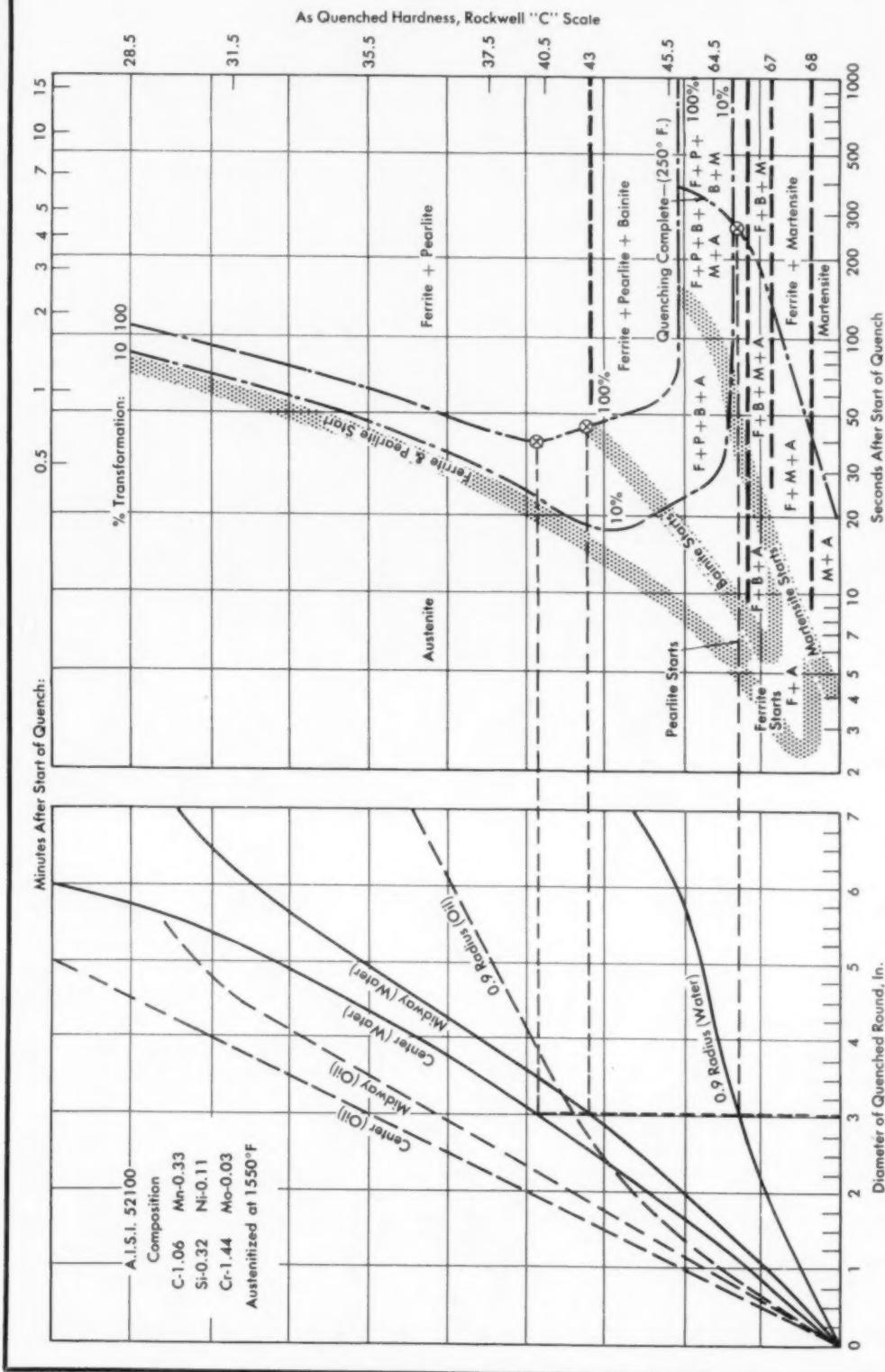


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# Heat Treatment Diagram for A.I.S.I. 52100

By D. J. Blickwede and R. C. Hess  
Bethlehem Steel Co.

See Explanatory Note  
in June issue, p. 114





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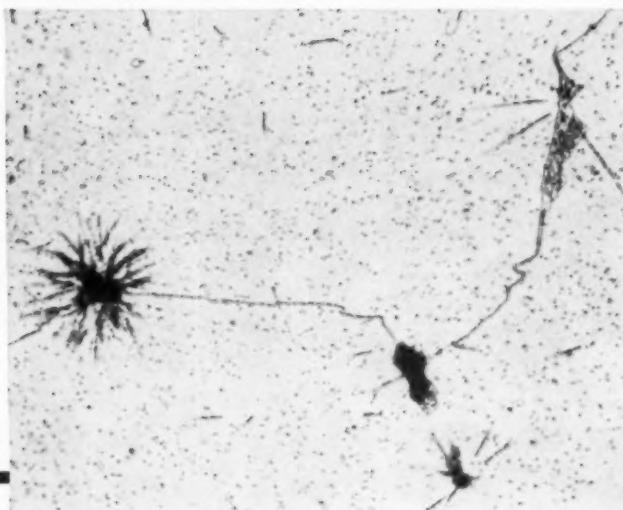


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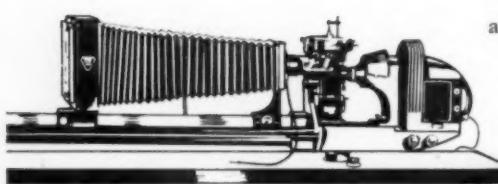
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*Fig. 1 - Typical Tensile Couple Pulled to Rupture. The threaded ends are aluminum and the thin disk is zirconium. Failure occurred in the parent metal and not at the interface. Actual size*

## Hot Pressure Bonding

By S. STORCHHEIM\*

New fabrication technique is useful in cladding a wide variety of metals. Experimental investigation shows that bonding pressure is a critical factor, and affects the microstructure and thickness of the intermetallic diffusion zone. This raises interesting possibilities for the study of binary constitutional diagrams. (L22, M24, 3-24)

IN RECENT YEARS a number of new metallurgical fabrication techniques have been introduced which have developed properties otherwise unattainable, and sometimes have reduced manufacturing costs. Examples of such techniques are continuous casting, hot pressing of metal powders, and powder metal rolling.

Another method is hot pressure bonding—that is, applying sufficient pressure to metal components while at moderate temperature to form a metallurgical bond between them. This has proven uniquely valuable in the cladding of a wide variety of metals for industrial purposes.

Among its advantages is the circumstance that metallic pairs which normally form brittle and

unusable intermetallics at the higher temperatures of fusion welding can be bonded with great strength and corrosion resistance even though these same brittle alloy zones appear in the microstructure. Since the pressure applied using this technique is hydrostatic in nature, any of the strong (even if brittle) intermetallics which form do not ordinarily develop microfractures. Also when the proper reaction precautions are

\*President and Technical Director, Metals Research and Development, Inc., Exeter, Pa. The author wishes to thank the Sylvania Electric Products Corp. for permission to use the data in this report, and also to thank A. Bartoszak, engineer in the nuclear division, Glenn L. Martin Co., for his help in preparing the article.

taken, bonding is uniform over the entire interface — at least as evaluated by metallurgical considerations and mechanical properties. Scrap losses are extremely low and reproducibility is extraordinarily high. Normally losses will come from destructive testing of samples; production acceptability is on the order of 95%. Knowing the necessary bonding conditions and with proper operation of present-day equipment, high production rates can be met of high-quality parts at a low price.

The following information largely concerns joints made between aluminum and nickel by this new technique. They are typical of the results obtained with hot pressure bonding of other systems, notably aluminum to copper, iron or zirconium.

The development approach is to make couples of the metals of interest and bond them while varying the conditions of temperature, pressure and time. The experimental couples are then tested for ultimate tensile strength. Interfaces of other specimens are studied under a microscope and zone growth is measured.

Apparatus for these hot pressure experiments is a small-scale replica of what can be utilized for production purposes. Basically, it includes a high-temperature die surrounded by an induction furnace, both placed in a water-cooled chamber which can be evacuated. Pressure is

Fig. 2 — Effect of Temperature on Ultimate Tensile Strength of Al-Ni Couples Bonded at Various Pressures

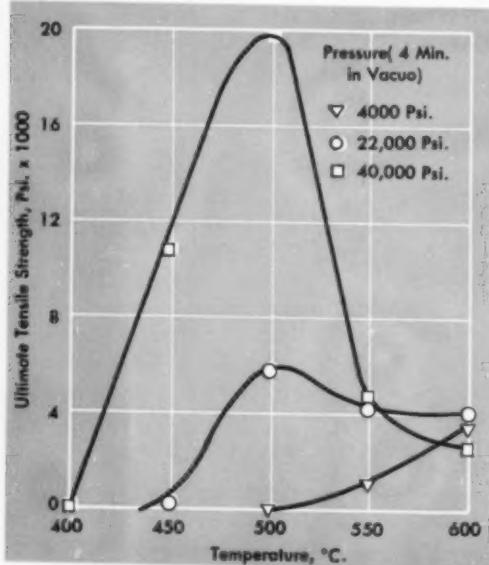
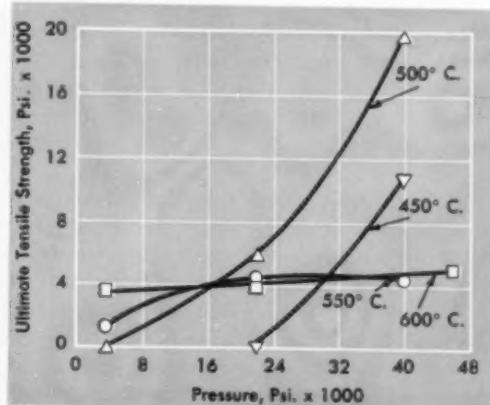


Fig. 3 — Effect of Time at Pressure of 22,000 Psi. on Ultimate Strength of Al-Ni Couples Bonded at Various Temperatures

applied to the specimen through the top of the chamber by a ram moving through a Wilson seal. Temperature is measured by thermocouples located in the die and punch near the samples. The temperature itself is controlled by means of a variable transformer.

The die materials used by the author are as follows: 18-4-1 toolsteel which can be used at 600° C. (1110° F.) at a maximum pressure of 22,000 psi., and Inconel "X" which can be used at 650° C. (1200° F.) at a maximum pressure of 30,000 psi. For still higher temperatures, graphite dies can be used; however, they are limited by the amount of pressure that can be

Fig. 4 — Effect of Bonding Pressure on Ultimate Strength of Al-Ni Couples Held 4 Min. in Vacuo at Various Temperatures



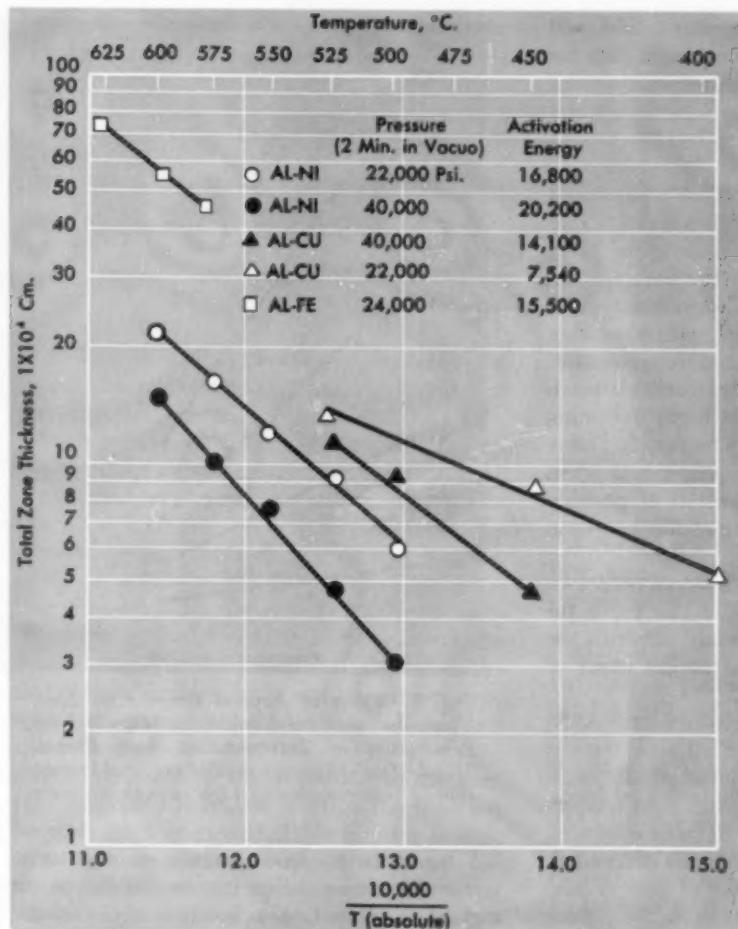


Fig. 5 - Effect of Bonding Temperature on Total Zone Thickness of Several Bimetal Systems. Activation energies in cal. per g.-atom

applied, which is about 4000 to 6000 psi.

In our work a tall round die with slightly tapered bore contained a tapered sleeve (split type) which provided a cylindrical central chamber, closed at the bottom with a closely fitting bottom punch which was stationary. Into this die was slipped a closely fitting round slug of aluminum, a disk of nickel of same diameter, and a second slug of aluminum. Finally the top part of the die chamber was filled by a punch.

This combination (already within the furnace coil and water-jacketed vacuum tank) was then closed and heated for a given time at given temperature, the tank meanwhile being evacuated to less than 5 microns, and the desired compacting pressure put on the ram for the correct time. This brings pressure directly down upon the top and from all sides through the tapered die liner. After reversing the cycle the bonded

slugs are removed and are ready for machining into test pieces.

A typical tensile specimen that has been pulled to rupture is shown in Fig. 1. Similar experimental couples are examined metallographically at high magnification, normally up to 1500 $\times$ .

Bonding is, of course, dependent upon the cleanliness of the mating interfaces. For production, chemical cleaning techniques are perfectly satisfactory when properly applied. However, to obtain engineering development data quickly, mechanical abrasion is recommended. The specimen interfaces are abraded immediately prior to assembly and hot pressing. In all the author's experiments this has been most expedient and readily reproducible.

A number of bimetallic systems have been studied by this process based on aluminum with nickel, copper, iron and zirconium. The Al-Ni system will be discussed in some detail with

regard to the effect of temperature, time and pressure on the bonds; some analogous data for the other pairs will be presented incidentally. From these data we can draw some general conclusions about hot pressure bonding.

Figure 2 shows the effect of temperature on the ultimate tensile strength of the bonds developed between aluminum and nickel. This graph (as well as graphs for the other three systems) indicates that temperature has a marked effect upon strength and that a general type of curve is generated. In general, with increasing temperatures (keeping other conditions constant) bond strength increases rapidly, reaches a maximum and then decreases — the latter indicating the formation of a brittle intermetallic alloy zone. Should the strength increase again when pressed at higher temperatures, it is possible that a modified or new intermetallic has been formed at the interface.

**Time** — A similar generalization can be drawn for the effect of time (Fig. 3). The curve for strength rises, peaks and descends, although the effect is not quite as marked as the effect of temperature on strength.

**Pressure** — The effect of pressure for the Al-Ni bond is shown in Fig. 4. In all four systems studied, the strength rose quite rapidly with increasing pressure, providing the right temperatures and times were used. In some instances, the strength leveled off and actually descended. This can be attributed to one of two causes: Either the alloy zone becomes excessively thick and strength starts to drop as noted above for the effects of temperature and time, or the alloy zone is inherently so brittle that the increased pressure causes fracture and the tensile strength decreases.

**Zone of Diffusion** — To understand completely the information obtained from mechanical tests, the bonded interfaces must be studied carefully under the microscope. Metallographic observations, as well as accurate determinations of zone thickness are invaluable aids in understanding not only the data obtained during the experimental development, but also any idiosyncrasies occurring during pilot plant and production runs.

Figure 5 shows the natural logarithm of the total zone formation as affected by the reciprocal of the absolute temperature. All the curves are straight lines. Activation energies for the curves are itemized on the graph.

When time is plotted against total diffusion thickness on log-log paper, the curves are straight lines for the Al-Cu and Al-Fe binaries.

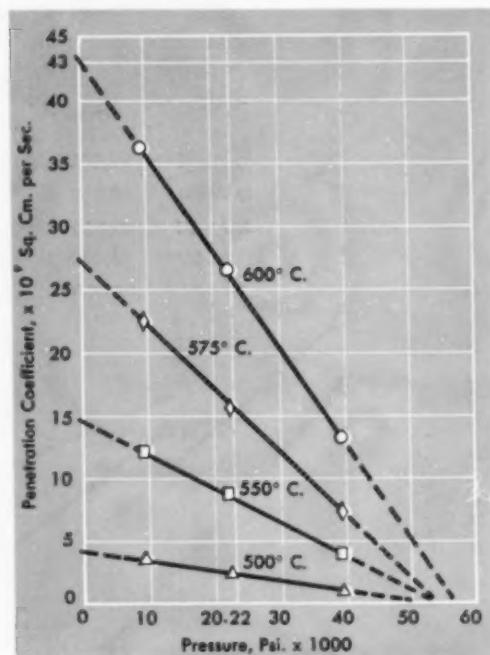
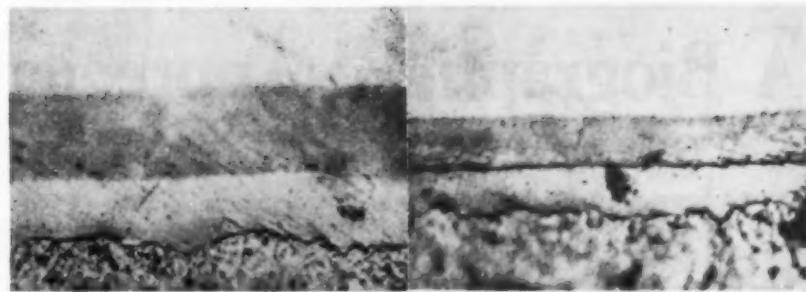


Fig. 6 — Effect of Applied Pressure on Zone Thickness of Al-Ni Couple, as Measured by Penetration of Intermetallics Into Parent Metal. Dashed curves predict eventual extinction of intermetallics at high enough pressure

When zone thickness (or the penetration of one of the intermetallics into one of the parent metals) is plotted as a function of increasing applied pressure, the intermetallic zone increases in the Al-Fe system. However, the reverse is seen for the Al-Ni system (Fig. 6). The dotted curves predict a complete extinction of all intermetallics at proper high pressures; actually, with increasing pressure the thickness of the intermetallic zone approaches zero, asymptotically.

Experimental work with the Al-Cu system indicates that it behaves in the same manner as the Al-Ni system (see Fig. 5).

One of the most startling aspects of our studies of solid state bonding is that it is possible to control the thickness (and in some instances, the actual formation of intermetallic alloy zones) by the proper application of pressure. This has interesting aspects, both theoretical and practical. Thus it is possible, by application of high enough pressure, to eliminate completely one of the Al-Ni intermetallic zones and almost quadruple the bond strength. This is shown by the photomicrographs of Fig. 7 showing two intermetallic zones in an Al-Ni system. The



darker of the two zones can be made to disappear completely by proper application of pressure.

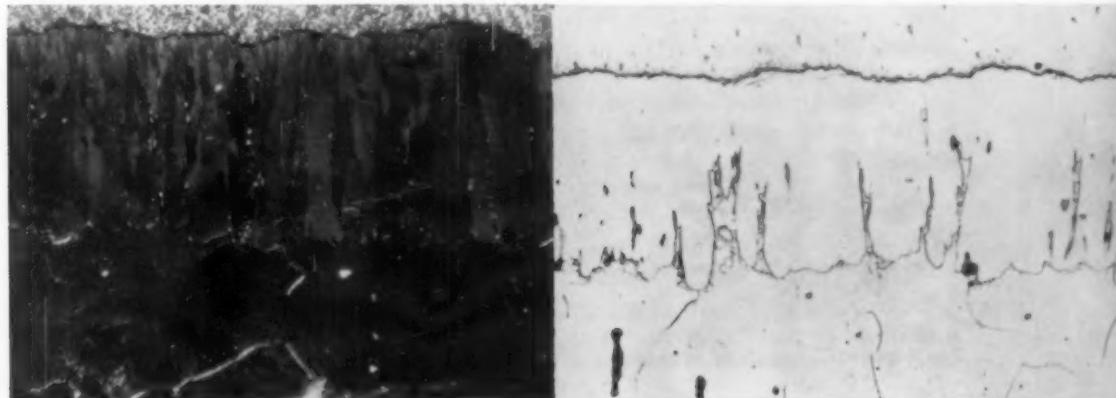
With continued increase in pressure the remaining intermetallics decrease in size with an accompanying increase in tensile strength of the bond. In fact, it is possible to develop strengths greater than the parent metals — that is, failure occurs within the parent metal rather than at the bond interface. This is graphically illustrated in Fig. 1 for the Al-Zr system. The bond strength at the interface was greater than that of the aluminum body, and rupture occurred within the parent metal (aluminum) during tensile testing.

The volumes of intermetallics which form play a decisive role as to whether the zone will be contracted or expanded. It may be possible to predict reactions occurring at the interfaces of untried systems during hot pressure bonding. The author's work on several systems of a proprietary nature conforms with the evidence presented here that the inhibiting effect of pressure pertains to systems where the intermetallics decrease in volume during formation. An increase in zone thickness appears to occur for intermetallics which expand during formation.

Fig. 7 — Two Intermetallic Zones in Al-Ni Diffusion Couple. Nickel at top, aluminum at bottom. Left micrograph shows sample hot pressed in vacuo at 10,000 psi. for 2 min. at 600° C. (1110° F.) When pressed at 40,000 psi. (at right) width of interfaces is considerably reduced. Unetched; 1500 $\times$

**Conclusion** — Hot pressure bonding offers a fast, cheap, reproducible, high-quality method for cladding one metal with another. It also presents some challenging problems to both theoretical and development engineers, particularly with regard to the effect of pressure during solid state bonding. Since it has been shown that pressure can have a decided effect upon the microstructure of a binary system, the point could be raised as to whether or not we should consider our present constitution diagrams as complete. Adding a third ordinate of pressure to such constitution diagrams should prove to be both an interesting and challenging problem to those who are investigating such areas.

Fig. 8 — Microstructure of an Aluminum-Iron Couple Hot Pressed at 600° C. (1110° F.) at 28,000 Psi. for 1 Hr. in Vacuo. Aluminum at top; iron at bottom. Unetched, 250 $\times$ . The micro at left taken under polarized light shows that the alloy zone is composed of long, thin columnar grains



# A Biographical Appreciation



**W. Paul Eddy**  
Executive Metallurgist

THE SOCIETY OF AUTOMOTIVE ENGINEERS now has another metallurgist for president — polyvalent W. Paul Eddy , chief of engineering operations of the Pratt & Whitney Aircraft Division of United Aircraft Corp., at East Hartford, Conn.\* Yet, strangely, he is but the second metallurgist-president in S.A.E.'s 52-year history, his predecessor being the late Henry Souther (died 1917), an S.A.E. founder, "father of S.A.E. standards", founder of Henry Souther Engineering Co. (chemicals and metals) of Hartford.

W. (for William) Paul Eddy also got into metallurgy through chemical engineering. He was born in Syracuse, N. Y., Dec. 3, 1899, and grew up there in an exciting time of industrial accomplishment. Halcomb Steel Co., now a component of Crucible Steel, had in 1908 put the first U. S. electric steel furnace into operation (described in *Metal Progress*, April 1956, p. 49). The Solvay Process soda ash works were already the largest in the world. John Wilkinson, another S.A.E. founder, was designing the multicylinder air-cooled engine which later powered the Franklin automobile.

When Paul Eddy, nicknamed "Hy" by family and schoolmates, entered Syracuse University he enrolled in chemical engineering. Because he was notably good at forensic logic he thought briefly of becoming a lawyer, but decided he was better in applied mathematics; furthermore, Syracuse industries in those days held out inviting prospects of well-paying jobs at which he could apply his knowledge, ability and leadership. Besides, he wanted to get married and set up home and family as early in life as possible. He did, marrying in his senior year Gail Cushing, a retired farmer's daughter. They have two daughters and a son, William P. (for Paul) Eddy III, an Annapolis graduate and Navy officer, and a present total of seven grandchildren.

The Paul Eddys live in a big colonial house in West Hartford, six miles and 17 motoring minutes from his Pratt & Whitney Aircraft office in East Hartford. They have a 36-ft. cruising sloop, named Hyades III after the crying baby-sitters of the Greek tippling god Dionysius. She is "large enough to do some real salt water sailing, but small enough so that I can handle her myself". When he is busy with the halyards, Mrs. Eddy mans the tiller.

Such is Paul Eddy's good life at the present high level of his engineering career.

His first job in 1923 was on tool and special

steels with Crucible Steel's Sanderson Works in Syracuse. Within the year he headed a group of ten chemists.

Next he was in New Haven with Geometric Tool Co. as chief metallurgist. In charge of the heat treating department and laboratory, he conceived and developed the induction heating of salt baths for hardening high speed toolsteel in 1927-28. At the same time he did what every successful professional man must do — share in professional society activities and publish professional papers. He joined  in 1925; in 1927 published an article on "Heat Treatment of Nondeforming Steels" in *Iron Age*. He also started the sort of community activities that are characteristic of successful U.S. businessmen. His beginning was as instructor in metallurgy in New Haven (junior) College, under sponsorship of A.S.M. His present extracurricular activity is as instructor in navigation in Hartford's U.S. Power Squadron.

His great swing upward to metallurgical engineering and pioneering really began in late 1928 when General Motors' Brown-Lipe-Chapin Division hired him as assistant head of the metallurgical and chemical laboratories. He came to be one of the pioneers in the applications of tungsten carbide tools and helped develop several new types of alloy steels for automotive gears.

Then G. M.'s Truck & Coach Division took him on, where he could vigorously apply his versatilities. He established and directed the metallurgical department, integrated chemical and metallurgical laboratories, set up specifications for materials and processes. He assisted in or directed development of the first monocoque-type rear-engine motor coach, hardened gray iron cylinder liners, copper-lead alloys for crankshaft bearings, first production use of shot peening and induction surface hardening, heavy plastic undercoating of motor vehicle chassis and bodies to prevent corrosion and abrasion, high-strength electric-furnace gray cast irons, heavy-duty lubricants containing inhibitors and detergents, the first successful automatic welding of armor plate, boron steels and the National Emergency (N.E.) steels.

In 1944 Pratt & Whitney Aircraft hired him as head of the materials engineering department. In two years he also took over responsibility for

\*Not to be confused with Pratt & Whitney Co., also of Hartford, one of its creators and one-time owners, which in turn is now a subsidiary of Penn-Texas Corp.

inspection, experimental construction, experimental hangar and flight testing and the experimental test laboratories. Much of his present work is "classified". In a plant so vast that legendary Paul Bunyan might freely hop, skip and jump, with machines that would make Joe Magarac feel puny, his engineering groups build and test air-cooled piston engines, turboprops and turbojets. An increasing number of components — notably the burners, turbines and afterburners of the turbojets — are of stainless steels and heat resisting alloys. Titanium alloys are used for many parts. An automatic butt welding process has been developed that produces joints so smooth they are almost imperceptible to the touch.

Very early in his career, when Paul Eddy was mainly concerned with heat treatment, he did much to take the hokum out of secret methods. As president of the S.A.E., in his talks to S.A.E. sections, he will similarly explain how problems of changing from piston to jet engines have been solved. He has a great talent for seeing facts in

logical relationships and for interpreting detail into the over-all objective.

For his offside diversions he may join in barbershop quartets. He also enjoys science fiction. More seriously, he regularly reads *Metal Progress*, *S.A.E. Journal* and aviation, business and news periodicals. He will read anything nautical that he can find. In "The Amateur Sailor", a folksy 1895 manual by Detroit's Alex McLeod that he recently acquired, he found a quotation that partly reflects his boyhood and his development into the polyvalent metallurgical executive that he is.

Wrote Alex McLeod: "A combination of things most desirable of attainment for the man or boy whose work is largely indoors is found in yachting — boat sailing. Yachting gives quick, sharp work for the amateur and affords time for rest after exertion. It promotes such high qualities of mind and heart as self-reliance, quick decision, prompt obedience and undaunted courage."

"Amen", says W. Paul Eddy.

MYRON WEISS

## News About Welding\*

SINCE THE American Welding Society named the recent annual meeting the "Adams National Meeting" in honor of the Society's first president, Comfort A. Adams (who happily was present to receive the richly deserved praise of those who are now carrying on along the paths he indicated so many years ago) it may be in order to recall that in the roaring 1920's there were many who claimed — not without some evidence — that welding was only slightly better than soldering and anyway it was only as good as the welder, and who knew whether the welder had been on a binge the night before. As a matter of fact, it required several years of well-planned study and development of new methods, equipment and machinery by leading firms in the welding industry, vigorously backed up by researches on fundamentals organized by Welding Research Council, to take the welding operation out of the repair shops and convert it into a reliable manufacturing tool in mass production. Like the single-minded young flier,

\*Staff Report.

who in 1927 announced to a skeptical world that he would fly the Atlantic and actually did it, men in the welding industry, too young and inexperienced to know that it couldn't be done, have advanced welding to frontiers which Dr. Adams could clearly see at the very beginning.

That is not to say that there are no new worlds to conquer — and some difficult ones at that, inhabited by men who are still thinking in terms of the 1920's. This is especially evident in the aeronautical industry, where caution is of course desirable. These men are usually bold in designing and using electronic gadgetry, yet they remain timid in adopting new metallurgical ideas except when driven to it. Coming from the sublime to the ridiculously simple is the story about the test missile whose inner control mechanism was to start functioning only after it had flown 300 ft. away. Uncounted hours of time were spent by electronics experts to devise something which would close the starting switch just 300 ft. away. No luck. Finally some simpleton asked why a piece of wire could not

be tack welded to the ramp and the other end to a switch lever in the missile. It was. It worked. Literally a triumph of elementary metallurgy over advanced electronics!

In keeping with the times, much emphasis at the Philadelphia meeting was placed on the welding of metallic systems in nuclear reactors and the effect of intense radiation on metals and joints. Where the word "joint" is used, welded joint is implied, for no other type of connection would be remotely tolerated in the handling of highly radioactive materials.

W. R. Hutchinson of Westinghouse Electric Corp., Bettis Field, Pittsburgh, in discussing a recent accident to a pressure vessel at the Canadian center for atomic research at Chalk River, gave a reassuring picture of what might be expected of carbon steel (A.S.T.M. A-212, Grade B) and welded joints therein. His tests were conducted in parallel on both heavily irradiated plate and on plate fresh from stock. No difficulties were encountered either during welding or during the testing which followed. No harmful effects were evident — that is, no peculiar changes or transformations were found, nor were the room-temperature properties lowered. To date such reactions as transmutations, decompositions, phase changes and "thermal spikes" have not shown themselves to be "serious radiation effects in reactor structural material". The author did mention the psychological effects: When the welder is working on metal which he knows has been heavily irradiated, and even though he is confident that all proper precautions have been taken to protect him from harmful radiation, his conscious or unconscious attitude is "much more likely to affect the quality of the weld joint than any neutron bombardment of crystal lattice".

**Joints in Clad Steels** — W. J. Leonard of Oak Ridge National Laboratories and J. C. Thompson of Union Carbide Nuclear Co. discussed the cracks which occur when a carbon steel weld bead is laid over a stainless steel weld in a clad steel vessel. They found that several welding materials would act as an effective barrier between the carbon and the stainless steel. Without such a barrier the low-carbon steel weld metal would be diluted with enough chromium and nickel from the stainless steel so the bead would consist of the nonductile phase martensite, and this is blamed for the weld cracking encountered when contraction on cooling throws high tensile stresses into the combination.

The procedures investigated by the authors

involved depositing stainless steel weld metal to a level just above the interface between stainless steel and carbon steel in the clad plate. At this point several alternate procedures were followed: In the first, the stainless steel root passes were machined flat and an ingot-iron insert was placed over this machined surface. The ingot-iron strip was tack welded to the carbon steel edges and carbon steel weld metal was deposited to fill the remainder of the butt joint. This, however, introduced a notch effect into the butt welded joint. A more acceptable method used an intermediate layer of ingot iron filler metal applied by hard surfacing welding techniques. The lower layer was stainless steel, as before, and the upper layer (over the ingot-iron separator) consisted of carbon steel. Elimination of the intermediate ingot-iron weld metal by substituting low-hydrogen weld metal deposited on 19-9 stainless steel weld metal very low in carbon, also provided an effective barrier between the carbon and stainless steel, and the authors concluded that although martensite and other transition phases were present, they did not seriously affect the ductility of the welded joint.

#### Midwest Welding Conference

At the end of January more than 250 welding specialists — engineers, scientists and production men — attended a two-day conference at the Armour Research Foundation in Chicago, jointly sponsored by the Chicago section of the American Welding Society.

This was the third annual conference of the sort, avowedly for the purpose of presenting an up-to-date review of the latest developments, of stimulating interest in welding problems still in their early stage of investigation, and to encourage new research.

**High-Frequency Resistance Welding** — What appeared to be the most newsworthy item was presented by Wallace C. Rudd of New Rochelle Tool Corp., New Rochelle, N.Y., in a description of a new machine for making tubing for high-temperature, high-pressure service. A flat strip of proper width and thickness is roll-formed into tube. The abutting edges are tack welded at the end and sprung open slightly so the gap forms a sharp V. The root of this V is pinched within a pair of rolls. Somewhat ahead of the root each edge is in contact with a terminal through which high-frequency electric current is led. This current hugs the edge of the joint and is so proportioned that it heats the metal

by resistance so the very root of the V comes up to forging heat at the same rate as the strip advances into the forming roll. This produces a forge weld since the edges of the seam are heated to a temperature in the plastic range and are then forged together under pressure. None of the metal reaches the melting point.

The flow of high-frequency energy is confined to the *surface* of the abutting edges, and results in a very small heat-affected zone. The unit uses a localized atmosphere of argon shielding gas when welding pyrophoric materials such as magnesium and zirconium. Tubing with walls only 0.010 in. thick has been made by this process.

**Distortion in welding** is a topic of perennial interest. Distortion may be caused by thermal contraction of the hot zone at and alongside a weld. According to J. R. Stitt of R. C. Mahon Co., Detroit, it can be remedied by the correct application of a heating torch; by the use of proper welding sequence; by the use of restraining members such as strongbacks; or by welding in pairs with the units placed back to back. He further suggested that the weldments should be stress-relieved before machining, since machining is likely to remove portions of the metal which are stressed in tension or compression, and thus unbalance the residual stresses in the remaining metal and cause further changes in shape or alignment.

One carried away the impression that each problem of distortion is unique, and will require intelligent design, procedure and after-treatment to mitigate its effects.

**Welding of Stainless** — At this same conference George Linnert of Armco Steel Corp., Baltimore, Md., talked about three of the major difficulties encountered in welding stainless steel — namely, notch effect, corrosion and contamination. The influence of notches on eventual service is no surprise to anyone who deals with weldments. Any notch will cause a concentration of stresses from applied loading which can be especially dangerous if the loading is rapid — impact. It also offers a fine location for the start of a fatigue failure when cyclic stresses are high.

In Mr. Linnert's opinion most people consider intergranular corrosion as the greatest cause of welding difficulties in severe service, but he believes that a combination of stress and corrosion — that is, stress-corrosion — is more dangerous. Finally, he cited contamination as a source of trouble. It may surprise many to learn that soldering flux containing HCl, used to attach a nameplate, will form a harmful

chloride precipitate. A soap or detergent containing sulphur — applied to a weldment to test pressure tightness — is also a known source of an expensive failure, an actual circumstance described by Marjorie R. Hyslop in her story "The Pitted-Tank Mystery" in *Metal Progress* for March 1955.

#### Western Metal Congress

Emphasis at the meetings of the American Welding Society at the Western Metal Congress in Los Angeles was on welding the "new" metals or metallic alloys useful in supersonic aircraft, rockets and missiles. The conditions of service — high stress at high temperature — dictate the use of materials other than the time-honored aluminum alloys, and the necessity for weight saving dictates the use of welds rather than riveted or other mechanical joints. These new metals and alloys — even old ones such as high-strength heat treated alloy steels — need new techniques; therefore much was said of fast heating in protective atmospheres.

**Carbon Dioxide Shielding** — One item on the program was entitled "A New CO<sub>2</sub> Welding Process" and was presented by Lee H. DeWald, consulting engineer for National Cylinder Gas Co. Mr. DeWald gave a good general discussion of protective atmospheres in arc welding, but dodged a number of questions from the floor about details of the new process — nor could anyone be found later in the Company's exhibit at the Western Metal Exposition who would do anything but refer the questioner to some absent conferee.

Mr. DeWald emphasized that CO<sub>2</sub> was not so much a "protective" gas as one which "excluded" the normal atmosphere. It certainly could not be thought of as an inert gas like argon or helium, but a rather active gas, readily ionized and therefore stabilizing the arc, and having a high affinity for hydrogen from whatever source. He said it "must be kept away from carbide formers", which possibly limits the process to low-carbon steels. One might imagine that at fairly high temperature the gas would be converted to CO and (at the focus of the arc itself) into carbon and oxygen — the latter being one of the reactive gases it is desired to exclude! At any rate the speaker said that various "refiners as used in electric steelmaking" were mixed in powder form and packed in the tubular electrode — an expedient which was thought to be more uniformly effective than though these refiners and slag formers were put into an elec-

trode coating. One might think that this expensive electrode would cost more than could be saved by the use of a cheap shielding gas like CO<sub>2</sub>. Other advantages might be claimed, such as a very short arc and a very deep crater, meaning deep penetration in a single pass along a T or butt joint.

A. F. Chouinard, research and development engineer for National Cylinder Gas Co. of Chicago, actually gave at the A.W.S. meeting in Philadelphia the paper he was scheduled to deliver in Los Angeles. Their trade name is "Dual-Shield". Electrodes are 1/16 to 3/16 in. diameter, and are designed for direct current, reverse polarity; cost is 38¢ per lb. and with 10% spatter or slag action the cost of deposited metal as electrode is 43¢ per lb. Maximum size of fillet welds is 5/16 in. and maximum plate thickness for satisfactory welding is 2 in.

Much attention to CO<sub>2</sub> welding was given at Philadelphia. Linde Air Products Co. demonstrated its version of CO<sub>2</sub> plus flux called "Unionarc", some details of which have been reported in the trade journals. General Electric demonstrated hard facing with CO<sub>2</sub> welding as well as welding in vertical or overhead positions with small-diameter wire. A. O. Smith Corp. had several demonstrations of the "C-Omatic" and "C-Omanual" welding processes, with specific emphasis on the salvaging of steel castings.

**New Russian Process** — In a corridor conversation at Los Angeles, John J. Chyle, director of welding research for A. O. Smith Corp. of Milwaukee and retiring president of American Welding Society, told the Editor about a new process described in the foreign press and the subject of a recent special report by the German Welding Society. Undoubtedly several American companies are investigating the principal features.

In general the idea is to weld under a slag blanket at temperatures high enough so the slag conducts the current from the wire to the parent metal. This is a true resistance welding process because there is no arc (although welding is initiated by an arc between the wire and the parent metal). After the electric current has been established the molten slag becomes conductive and the arc is extinguished.

The advantages of this process seem to be a high rate of metal deposition with a high current efficiency and sound, good-quality weld metal. Because of the tremendous amount of heat which is generated, the weld metal cools very slowly and the metallurgical effect of this cooling rate is probably more pronounced than in other processes. It has been reported that the Russians have used this process for heavy pressure vessels and fabricated weldments, and photographs of this equipment indicate that it has been developed to a high degree.

## Atomic Welding

Extract from an article on "The Atom and the Workingman" by John Lear, science editor of *Saturday Review*, May 4, 1957:

"Let us consider welding.

"All that a welder used to need was a sharp eye and one strong steady hand. He pulled two pieces of metal as close together as possible, then whisked his torch and filler rod across (a flat surface) or around (a pipe) the joint in a dazzle of sparks. Protuberance at the welded juncture was taken for granted. Little thought was given to stalactites of slag that accumulated on the underside.

"Atomic welding, in contrast, requires two hands — one to

hold the torch and the other the filler rod — and delicate coordination between them. The surface of the joint must have no pock nor pimple that could germinate a weakness, so the metals to be joined are first aligned to parallel exactly but not to meet, and the span between is securely tacked at three or four points before the weld proceeds. A curtain of inert gas (argon, helium, or nitrogen) is thrown around the flame of the torch and blanketed on the opposite side of the metal to screen out oxygen, which could open an unseen crevice to be attacked by corrosion or by the conspiracy of stress and pressure which uniquely typifies atomic

chemistry. The metal itself is kept almost hospital-clean; it cannot be touched by the fingers. Sometimes the welder is required to work with rubber gloves inside a vacuum hood. Apprentices take three years to learn the new technique. Experienced welders are not at home with it in less than three months. A skilled man spends five times as long in the making of an atomic weld as a pre-atomic. The work is rigorously inspected at every step — Oak Ridge National Laboratory having six inspectors for only 20 welders. Part of the inspection is an X-ray picture."

We thought you'd like to know.

# Grain-Boundary Carbides in Extra-Low-Carbon Stainless

By R. O. STEINER and P. S. TROZZO\*

EARLY IN THE USE of chromium-nickel stainless steels it was discovered that after heating in the temperature range 800 to 1400° F. such metal became very sensitive to intergranular corrosion by acidic solutions normally resisted perfectly — the metal became "sensitized", as it was said. Some basic research by Messrs. Bain, Aborn and Rutherford in the U.S. Steel Corp.'s research laboratory in 1931 and 1932 indicated the cause, namely, precipitation of carbides rich in chromium at the grain boundaries with the simultaneous impoverishment of the adjoining metal of chromium to a point where its corrosion resistance was greatly impaired. These carbides were precipitated from what appeared to be a uniform solid solution of iron, carbon, chromium and nickel (austenite) — apparently unstable in the temperature range mentioned.

The evidence pointed to several methods of curing the trouble — or "stabilizing" the alloy:

1. Fragment the austenitic grains by cold work, precipitate the chromium-iron carbides at grain boundaries and slip planes, and continue the heating until the impoverished grain boundaries are replenished by diffusion of chromium from within the grains.

2. Add enough of a strong carbide former such as columbium or titanium so the carbides which precipitate from metastable austenite during high-temperature use will be columbium carbide or titanium carbide.

3. Drive carbon so low in the chromium-nickel alloy that it is less than the solid solubility in austenite at the sensitizing temperatures.

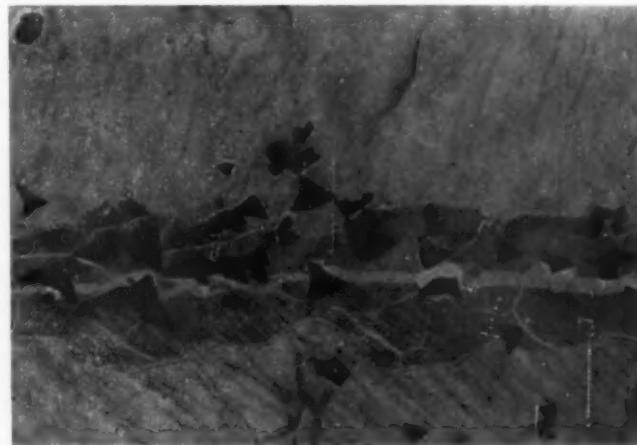
The second expedient mentioned above was quickly adopted by industry and such steels have long been listed in the A.I.S.I. standards as Types 321 and 347, stabilized with titanium and

A "sensitizing" heat treatment precipitates complex carbides,  $(Fe, Cr)_{23}C_6$ , whose locus favors one of the abutting grains. (M27d, M21e, M22h, 1-4; SS, 14-18)

columbium respectively. The third cure is not nearly so easy to effect in the steel plant; much later did the "extra-low-carbon" steels appear commercially and in the A.I.S.I. list of standard designations as Types 304 L and 316 L, wherein carbon is specified as 0.03% max.

While driving the carbon down this low in the 18-8 family of steels was effective in preventing intergranular failures in many services,

Fig. 1 — Electron Micrograph of Extraction Replica of Sensitized Type 304 L Stainless Steel Showing Precipitate of Complex Iron-Chromium Carbide at Grain Boundary and Zone of Chromium Depletion. Nature of gray "river" at grain boundary is unknown. Etched with Vilella's reagent. Original magnification 15,000 $\times$ ; reproduced at 10,000 $\times$



\*Applied Research Laboratory, U.S. Steel Corp., Monroeville, Pa. Mr. Steiner is now with Esso Research and Engineering Co., Linden, N.J.

intergranular precipitates have been observed in steels considerably lower in carbon. This paper will report briefly on a thorough study of the microstructure of a heat of 304 L sensitized by heating 2 hr. at 1250° F., then quenching in water. Its chemical analysis was 18.32% Cr, 10.32% Ni, 0.016% C, 1.68% Mn, 0.50% Si, 0.019% P and 0.019% S.

It had been microscopically examined at the mill, and an intergranular network was found which the metallgrapher assumed to be carbide. Since he was not sure of his findings, he sent the samples to the Corporation's Applied Research Laboratory for examination under the electron microscope and by electron diffraction.

Although grain-boundary carbide precipitation was to be expected in this unstabilized sensitized stainless steel, it seemed unlikely that enough carbide could have precipitated to form a uniform layer around individual grains in metal whose carbon content was so very low. It was hoped that the considerably higher resolving power of the electron microscope would give a better idea of the nature of the precipitate. It was also highly desirable to determine the composition of the grain-boundary carbide by diffraction techniques which have already been successfully used by others.

**Techniques** — First, a sample was mechanically polished and the surface deeply etched, a procedure which left the insoluble carbides in relief. Then, a diffraction pattern was taken with the beam at a very low angle of incidence. The resulting pattern (Table I) corresponded to the complex carbide  $M_{23}C_6$ .

To make sure that the diffraction pattern thus obtained was due to the grain-boundary deposit, a microscopic extraction technique was used similar to the one described in 1953 by R. M. Fisher in A.S.T.M. Special Publication No. 155\*. A replica of the deeply etched surface was obtained, which not only gave a good picture

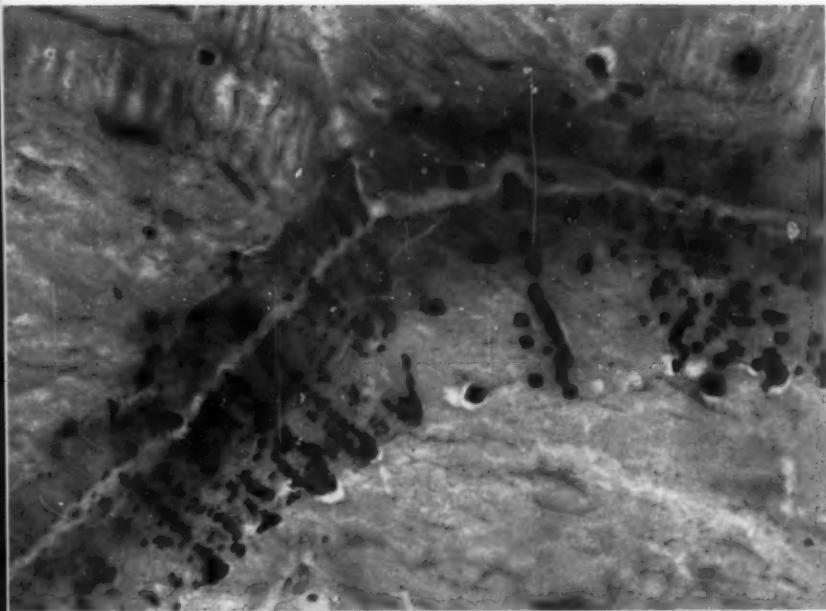
### Diffraction Patterns for $(Fe, Cr)_{23}C_6$

| THEORETICAL<br>INTERPLANAR<br>SPACINGS* | MILLER INDICES<br>OF NET PLANES<br>(HKL) | OBSERVED INTERPLANAR SPACINGS |              |
|---|--|-------------------------------|--------------|
|   |  | REFLECTION                    | TRANSMISSION |
| 6.13 Å                                  | 111                                      |                               |              |
| 5.31                                    | 200                                      | 5.34 Å                        |              |
| 3.76                                    | 220                                      | 3.79                          |              |
| 3.20                                    | 311                                      | 3.24                          |              |
| 3.07                                    | 222                                      | 3.10                          |              |
| 2.66                                    | 400                                      | 2.66                          |              |
| 2.44                                    | 331                                      | 2.45                          |              |
| 2.38                                    | 420                                      | 2.39                          |              |
| 2.17                                    | 422                                      | 2.19                          | 2.15 Å       |
| 2.04                                    | 511,333                                  | 2.05                          | 2.04         |
| 1.88                                    | 440                                      | 1.89                          | 1.86         |
| 1.795                                   | 331                                      | 1.80                          | 1.79         |
| 1.77                                    | 422,600                                  | —                             | 1.76         |
| 1.68                                    | 620                                      | 1.66                          | —            |
| 1.62                                    | 533                                      | 1.61                          | 1.62         |
| 1.595                                   | 622                                      | 1.59                          | —            |
| 1.535                                   | 444                                      | —                             | —            |
| 1.49                                    | 551,711                                  | 1.49                          | —            |
| 1.475                                   | 640                                      | —                             | 1.46         |
| 1.42                                    | 642                                      | 1.42                          | —            |
| 1.385                                   | 553,731                                  | 1.39                          | 1.39         |
| 1.33                                    | 800                                      | 1.33                          | —            |
| 1.30                                    | 733                                      | 1.30                          | —            |
| 1.29                                    | 644,820                                  | 1.28                          | 1.29         |
| 1.25                                    | 660,882                                  | 1.25                          | 1.25         |
| 1.225                                   | 555,751                                  | 1.23                          | 1.22         |
| 1.22                                    | 662                                      | —                             | —            |
| 1.19                                    | 840                                      | 1.19                          | —            |
| 1.165                                   | 753,911                                  | 1.17                          | —            |
| 1.16                                    | 842                                      | —                             | 1.16         |
| 1.135                                   | 664                                      | —                             | 1.13         |
| 1.115                                   | 931                                      | 1.12                          | —            |
| 1.085                                   | 844                                      | 1.09                          | 1.09         |
| 1.07                                    | 771,755,933                              | 1.07                          | 1.07         |

\*Calculated for  $a_0 = 10.625 \text{ \AA}$

of the etching characteristics of the surface, but also contained the extracted particles. The composition of the particles was then determined by transmission electron diffraction. Again the pattern obtained corresponded to the compound  $(Fe, Cr)_{23}C_6$  as shown in the fourth column of the table above.

\*Fisher's extraction replication technique involves a two-step etching process. First, the polished metal surface is etched, causing the carbide particles to stand out in relief. A thin plastic coating is then placed on this surface which not only duplicates the surface contours but also, at the same time, partly embeds the protruding particles. The sample is then re-etched through the plastic film, thus loosening or undercutting the carbide particles. When stripping the replica, the particles remain embedded in the replica in the same relative position they occupied in the original steel surface.



The electron micrographs Fig. 1 and 2 of the extraction replicas showed a clearly defined, deep-etching zone, about 20,000 Angstroms wide (10,000 Angstroms - 0.04 mil or 0.00004 in. - in each grain) all along the grain boundaries. Practically all the precipitated particles were concentrated here.

However, the particles were not distributed at random along the grain boundary, but favored one of the two opposing deep-etching zones - in the upper grain in Fig. 1 and the lower grain in Fig. 2. We believed that the relative crystallographic orientation of the grains was partly responsible for this. We also noted that the twin boundaries and the twin bands seem to have a distinct influence on the pattern of precipitation in the adjacent grain. This is possibly due to induced stresses.

Another interesting feature that is not understood is the formation of carbides in chains or loops with their axes aligned normal to the grain boundary, as shown in Fig. 2. In this sample the carbide formation extends beyond the zone of rapid etching. (Occasionally, single particles were found outside the grain-boundary zones, but these had moved from their original position in the course of replica preparation.)

#### Conclusions

From the data and the pictures obtained in this investigation, the following conclusions can be drawn:

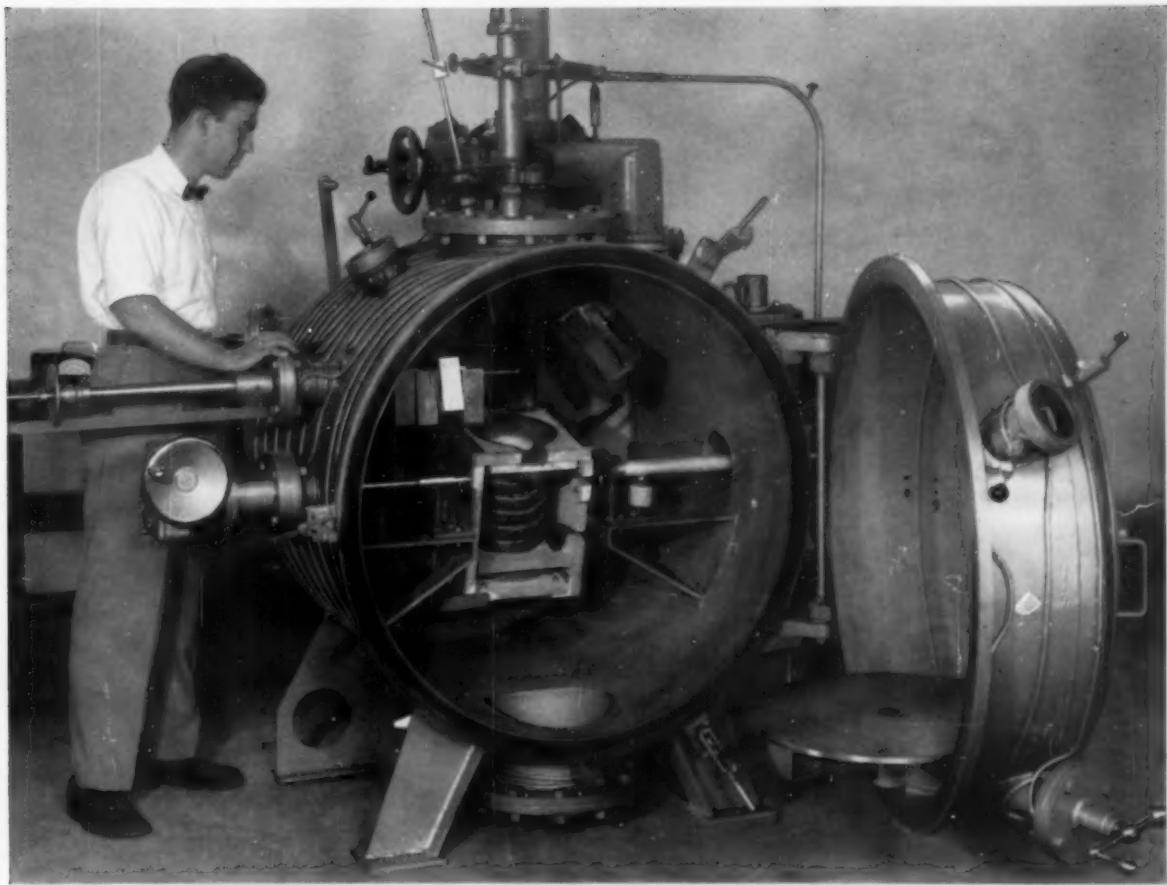
Fig. 2 - Alignment of Carbide Particles Extending Into the Grain Apparently Beyond Grain-Boundary Region. The black spots in both electron micros are actual carbide particles embedded in the plastic replica. Etched with Vilella's reagent. Original magnification 15,000  $\times$ ; reproduced at 10,000  $\times$

The carbides that precipitated in the grain boundaries of this low-carbon stainless steel have the composition  $M_{23}C_6$ , but we are unable to say how many of the 23 metallic atoms are iron and how many are chromium. Associated with the carbide precipitate, a narrow, rapid-etching zone was observed along the grain boundaries. It seems reasonable to assume that such zones are identical with the regions that are susceptible to intergranular corrosion in sensitized metal. Since there was a pronounced precipitation of complex carbide particles along grain boundaries, the grain-boundary region had a lower chromium and carbon content than the bulk of the grain.

A depletion of these two elements favors the formation of low-chromium ferrite when the austenite cools from the sensitizing heat. (Such ferrite has actually been identified by X-ray diffraction by E. J. Dulis and G. V. Smith (*Transactions*, 1952) and B. Cina (*Journal of the Iron and Steel Institute*, 1955). The very sharp outline of the rapid etching zone also gives the impression of a phase-boundary rather than a parting limit or passivity limit.

The amount of carbon precipitated in the grain-boundary region appeared to be considerably higher than the amount of carbon originally present, and thus it seems that much of the carbon must have diffused from the bulk of the grain to the grain-boundary region during the 2-hr. heating at 1250° F. - a temperature where the diffusion rate of carbon is known to be relatively high.

Although considerably more research will have to be done to clarify some of these findings, it has again been shown that the electron microscope and the electron diffraction camera are indispensable tools for the fundamental study of intergranular corrosion and of precipitation phenomena in general.



Featured at the 1955 National Metal Exposition, this new NRC Model 2555 fifty pound vacuum induction furnace provides ease of operation, ingenious charging and alloy addition devices, rotary mold table. It is already in use by aircraft companies, engine manufacturers, investment casters, specialty steel producers.

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Have your representative call

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## Correspondence...

### Steel Globules in Gilding Metal

WASHINGTON, D.C.

The curious photomicrograph alongside shows perfectly round globules of martensitic steel entrapped in a welded overlay of gilding metal on a steel base. The small globule is 0.027 in. from the fusion line, and the larger one 0.039 in. Thickness of the finish machined gilding metal is 0.090 in.

The Knoop hardness of the globules is 640 (equivalent to Rockwell C-55 to 56), and the hardness of the gilding metal is approximately equivalent to an S.A.E. 1140; the composition of the gilding metal is 90% Cu, 10% Zn.

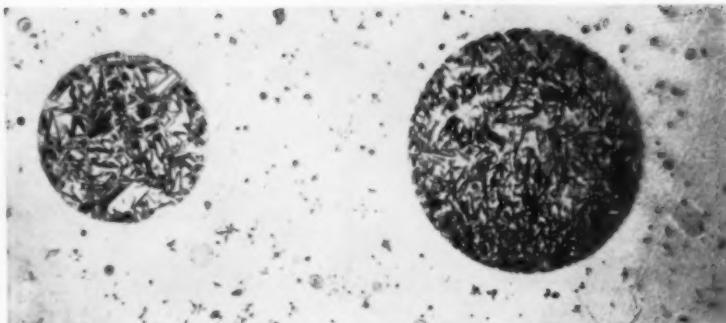
The photomicrograph was made by T. L. Stivers and S. L. Tolman of our metallographic laboratory.

P. H. AUSTIN  
Materials Engineer  
U.S. Naval Gun Factory

### Acid Polishing of Metallographic Specimens

UTICA, N.Y.

Polished specimens for metallographic examination must have certain attributes as follows: (a) a flat surface edge to edge, (b) a scratch-free surface, (c) retention of inclusions, (d) absence of flowed metal, and (e) be a representative sample. A procedure which has been used successfully to polish high-temperature alloys and some alloy steels uses a new technique.



*Perfectly Round Globules of Martensitic Steel Picked up From Base Metal During Deposition of Gilding Metal. 500 X*

Preliminary steps are conventional: The sample is mounted usually in bakelite and given a flat surface on a grinder using belts of aluminum oxide grit with a resinite bond. It is rough polished on a horizontal mechanical wheel for most routine work. Silicon carbide disks from 180 to 600 grit size are preferred, since water can be used on them without loosening the grit. For inclusion counting and polishing certain alloys, this preliminary polishing is done by hand using silicon carbide or emery papers. For final polishing several types of cloth wheel have been tried, and the preference is for billiard cloth. The abrasive is a commercially available alumina powder, about 0.5 micron, in a distilled water suspension.

The new variation is to use an acid solution in combination with the abrasive. The stock solution used is a modified Kalling's reagent. This reagent, which we frequently use for etching, consists of 2.5 g. of copper chloride dissolved in 50 ml. of 95% ethyl alcohol and 50 ml. of

concentrated hydrochloric acid. For use in polishing, distilled water is substituted for the alcohol. Before use, 1 part of the stock solution is diluted with 10 parts of distilled water. A polyethylene wash bottle is used to apply the working solution to the polishing cloth.

Usually, the abrasive suspension is applied to the billiard cloth and then a small amount of acid. Experience will indicate the exact amount to use. Further applications of acid are made only after additions of abrasive.

It was found that the acid attacked the surface of the brass polishing wheel and the draining well. Frequent flushing with water during and after polishing reduces this effect. For further protection the draining well should be painted with an acid resistant paint. If this is not feasible a lacquer such as label glaze or a rubber cement will protect the surface for short periods.

The face of the wheel cannot be treated in a similar way. It was found that thin sheets of polyethylene can be put on the wheel under the billiard cloth. After both are fastened securely with the holding band, they are trimmed to fit.

# Using "free machining"

# Olympic FM

(D-2 type)

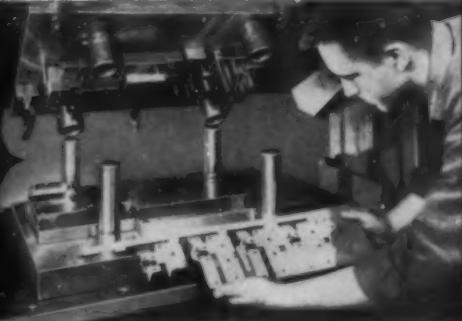
## die steel...

Middlestadt Machine Co.,  
Baltimore, Md.



Six station progressive die

... saved  
over 100  
machining  
hours  
on this  
die!



Five station progressive die

... saved  
over 70  
machining  
hours  
on this  
die!

In the manufacture of these long-run dies, used to produce brackets for hanging venetian blinds, the Middlestadt Machine Co. reported a savings of 15% in the machining times. This savings, attributed to the "free-machining" characteristics of Olympic FM, was important because the total machining time approximated 1125 hours.

In addition to these savings, Middlestadt, one of the largest precision die shops in the mid-East, also noted these additional advantages of Olympic FM: (1) full uniformity in the steel; (2) excellent non-deforming characteristics during heat treatment; (3) large range of stock sizes available for fast delivery.

Use Olympic FM high carbon-high chromium  
die steel for long run dies...



... and you, too, can effect savings in machining time while gaining outstanding performance advantages. These plus factors are a direct result of Latrobe's exclusive DESEGATIZED® process of manufacture where the carbide particles and alloy sulphides are uniformly dispersed throughout the steel.

Over 250 sizes of Olympic FM are readily available from ten conveniently located warehouses... Call your Latrobe representative today!

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## HOW Cambridge help Heat Treaters



### Continuous Annealing

**MOVING BELT** carries a stream of brass light bulb ferrules through furnace for continuous uniform annealing at 1400° F.

**OPEN MESH** of Cambridge belt allows free circulation of heat around load so that hot spots are eliminated. Open mesh construction also permits rapid drainage in wet processes such as quenching and washing.

**ALL-METAL BELT** withstands heat up to 2100° F. (as in copper brazing) without damage, provides lasting strength because there are no seams, lacer or fasteners to break or wear.

**SPECIAL RAISED EDGES** hold parts on belt, are typical of a variety of side and surface attachments available to hold the product during flat or inclined movement.

**Cambridge Woven Wire Conveyor Belts** are made in any size, mesh or weave, from any metal or alloy, and can be used under a wide range of conditions . . . hot or cold, wet or dry. Call your Cambridge Field Engineer to discuss how you can cut costs with continuous processing on woven wire conveyor belts. Look for his phone number under "Belting, Mechanical" in the Yellow Pages or write for FREE 130-PAGE REFERENCE MANUAL.



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## Woven Wire Belts

### increase uniformity, speed production

By providing continuous movement through heat treating cycles, woven wire conveyor belts eliminate batch handling, increase product uniformity and production capacity in annealing, brazing, quenching, tempering, sintering, etc. EXAMPLE:

## Acid Polishing . . .

This polyethylene sheet completely protects the wheel from the corrosive effect of the acid.

The use of this technique has cut the total polishing time considerably. Formerly it was necessary to continue on another wheel with a finer abrasive. Now all samples are completed on the acid wheel. Another advantage is that the carbides in high-temperature alloys are not polished in relief. The surface is almost completely free of flowed metal after the first polishing. Usually a light etch and repolishing rids the surface of the remaining flowed metal. The specimen is rendered scratch-free in less time than by other methods. Finally, nonmetallic inclusions are retained.

EDWARD O'MARA

Metallographer

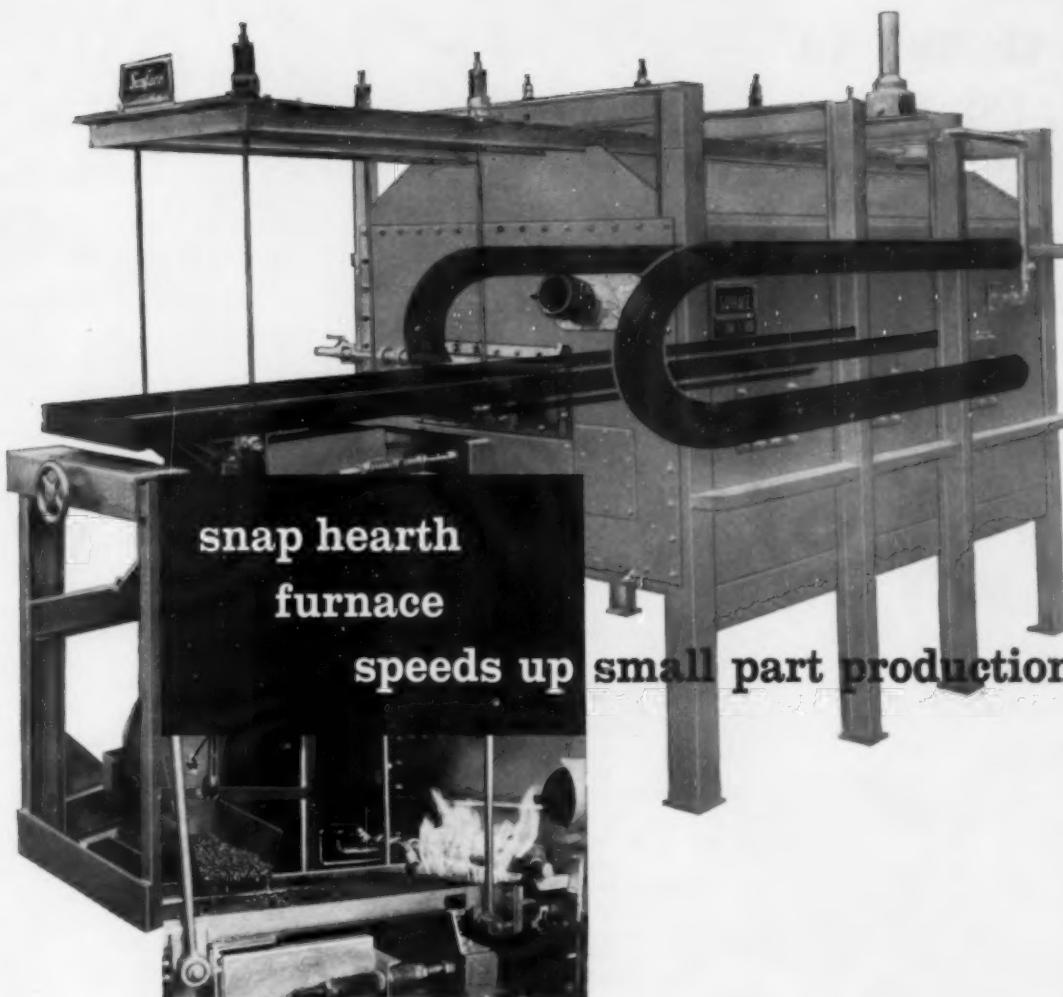
Utica Drop Forge & Tool Div.  
Kelsey-Hayes Co.

## The "Solid State Engineer"

NEW YORK CITY

The "Critical Point" in *Metal Progress*'s April issue again states the fact that the number of new engineers fed into American industry annually by our educational system is not likely to increase notably in the foreseeable future. This emphasizes the idea that those new engineers we do receive should be used with care — their capabilities not wasted on routine tasks. Another conclusion is that their scholastic training should be well adapted to today's needs.

One foreseeable need is for young men who can devise compositions and fabrication methods for metallic alloys, metallic compounds and mixtures of the two which can withstand the operating conditions in the forthcoming machinery of the jet engine and atomic eras. In my opinion, lack of urgently needed new materials (which obviously is preventing the construction and operation of many new and useful devices) stems from the lack of the right type of engineers. Most of our first-class engineers are highly specialized, which is an advantage in many branches of engineering, but is defi-



**Surface Snap Hearth Furnace**  
**speeds up small part production**

The quantity and quality of small parts can be increased by controlled atmosphere heating and quenching in this new Surface® Snap Hearth Furnace. Production rates up to 500 lbs/hr are attained in many plants.

This is the first suspended hearth furnace to use suction type radiant tube firing, which eliminates a muffle and its extensive replacement problems. Another important feature is the hearth, which snaps to move the parts a short distance at regulated intervals.

Combined with Surface atmosphere generating equipment, the Snap Hearth Furnace is especially efficient for clean hardening, dry cyaniding, carbon restoration.

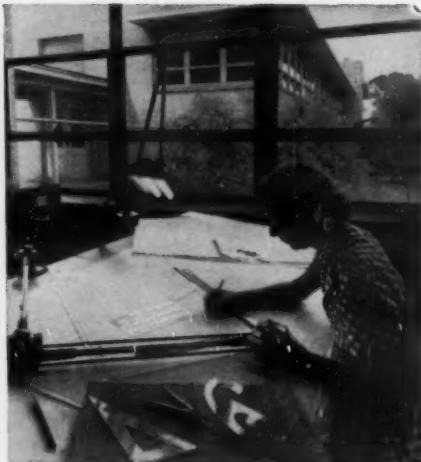
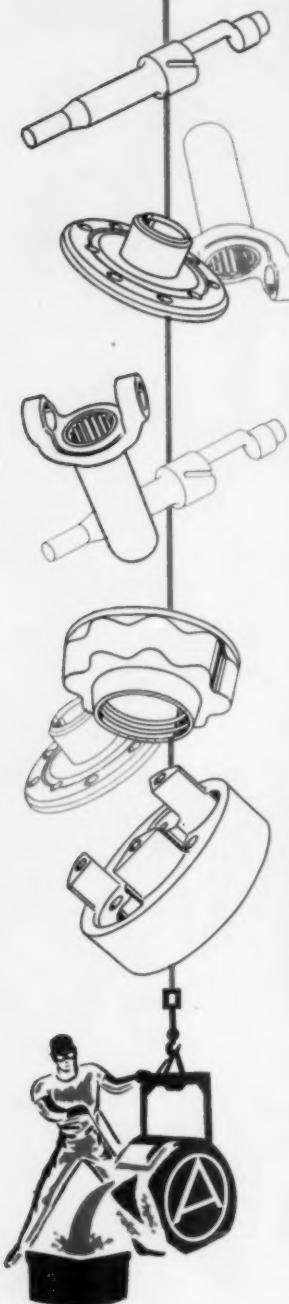
*Write for Bulletin SC-173.*

Surface Combustion Corp., 2377 Dorr St., Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

*wherever heat is used in industry*



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Saving your dollars with good, accurate castings is a 67-year old habit at Albion Malleable Iron Co.

Devising ingenious ways to shorten time between idea and delivery, creation of new designs, engineering new methods for more rapid, economical manufacture and delivery—all are routine benefits you realize when you specify AMICO—the experienced source that guarantees higher quality.

Remember, too, that Albion's ferritic and pearlitic malleable castings offer a new freedom of design, the elimination of excess metal for lower finishing costs. They afford unusually high wear resistance with excellent bearing properties. Also, maximum rigidity, prolonged fatigue life and amazing yield strength. They have a fine uniform grain structure for mirror-smooth finishing qualities and are adaptable to localized hardening.

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ALBION'S RESEARCH AND DEVELOPMENT LABORATORY—design engineers and production specialists are ready to help you design better products that can be made at lower cost—with-out obligation.

**ALBION  
MALLEABLE  
IRON CO.**  
ALBION, MICHIGAN

## Solid State Engineer . . .

nitely a disadvantage for the development of new materials.

During the last few years a new branch of physics has been developed known as solid state physics. During these years the solid state physicist got a deep insight into the solid state, its structure and its behavior. For practical use, however, this development of physics has to be followed up by the engineer, and (in analogy to the solid state physicist) what is needed is the "solid state engineer".

He should no longer be a specialist, as are today's metallurgists or ceramic engineers, or the chemical engineer working in the field of plastics. The solid state engineer has to receive a much broader education than the more or less narrow-minded specialist; he has to be a broad-minded combination of a mechanical, metallurgical, ceramic and chemical engineer.

A new and broader type of education is needed for these engineers. It will require a revision of the usual postgraduate courses of study, but rich rewards will flow back into the progressive university whose engineering faculty recognizes the need and prepares to meet it.

HENRY H. HAUSNER  
Vice-President  
Penn-Texas Corp. (Nuclear Div.)

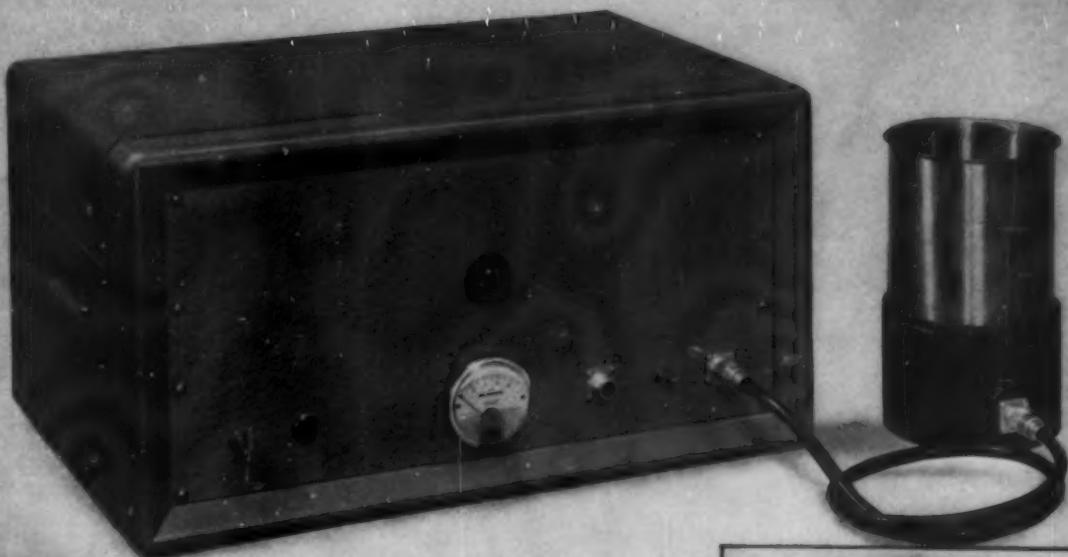
## Powder Metallurgy . . .

(Starts on p. 95)

15 min. is sufficient. Homogenization of iron-silicon alloys was also improved by this technique.

**Fundamentals**—The physical and metallurgical processes which act to convert a friable compact of metal powders or compounds into a rugged piece of high utility are fascinating topics to anyone who gives the process more than casual attention. Not only are these intellectual excursions stimulating in themselves, but it is obvious that important commercial developments must be based on a better understanding of the fundamentals. It is not surprising therefore that such topics received considerable attention. In particular, G. Kuczynski of Notre Dame University discussed the relative importance of plastic

No. 1950  
ULTRASONIC CLEANER  
FOR METALLOGRAPHY



No. 1952 Positioning Clamp and Automet Holder

This new scientific development is ideal for cleaning metallographic specimens. It removes the hazard of carrying abrasive particles from a coarse grinding stage on to a finer grinding stage. The cleaning is accomplished quickly, thoroughly and at low operating cost. No skill is required. Additional speed and convenience is achieved by using an additional Transducer

Beaker. The positioning clamp is required to accommodate the specimen holder from the Buehler Automet automatic polishing attachment.

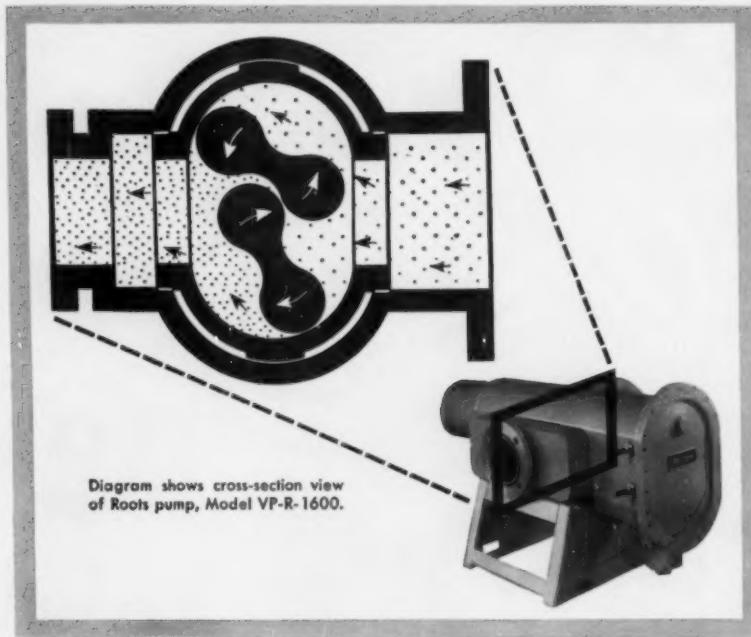
|   |          |
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| No. 1950 ULTRASONIC CLEANER .....                     | \$495.00 |
| No. 1951 EXTRA<br>TRANSDUCER BEAKER .....             | \$130.00 |
| No. 1952 POSITIONING CLAMP<br>for Automet Holder..... | \$ 22.00 |



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Now you can achieve completely dry pressure in the  $10^{-1}$  to  $10^{-5}$  mm Hg range using only a *mechanical* high-vacuum pump.

Probably the world's fastest pump in this range, the new Roots pump works without the aid of oil or steam vapors.

A pair of finely machined rotary pistons do the pumping. The pistons never touch one another or the pump casing, so the Roots pump needs no oil sealing. It cannot contaminate a system with backstreaming vapors.

### Consider these other advantages:

**1. Speed.** The model shown above has a throughput of 10,400 micron cu. ft. per minute at 10 microns.

**2. No shaft seals, no leaks.** Motor operates within the vacuum.

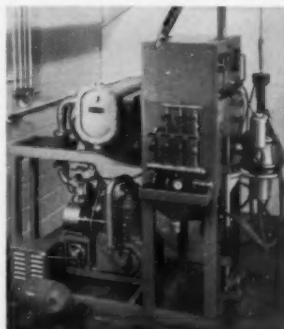
**3. No by-pass or valving.** Roughing is done directly *through* the pump.

**4. Quiet.** The Roots pump does not vibrate when in operation.

### 5. Low power consumption.

Under a license with the manufacturer, Heraeus (Hanau, Germany), CEC is exclusive agent for all seven models of the Roots pump in this country.

For data on performance and theory of operation, write for Bulletin P8-20.



Heraeus Vacuum Arc Melting Furnaces are also available from CEC. Note Roots pump used. Furnace melts "buttons" to ingots. Particularly useful for obtaining pure samples of metals with high melting points. Information in Bulletin P4-28.



**Consolidated Electrodynamics**

**Rochester Division, Rochester 3, N. Y.**

*formerly Consolidated Vacuum*

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## Powder Metallurgy . . .

flow, volume diffusion, surface diffusion, evaporation, and condensation. He believes that the radius of curvature of the "neck" formed by bonding of quasi-spherical shapes of the powder also has considerable influence. He finds that glass sinters by viscous flow, while metals sinter mainly by volume diffusion. On the other hand, rock salt sinters by evaporation and condensation. One interesting technique employed in his sintering studies is the alternate wrapping of nickel and copper wires so that they are in close contact, and then exposing the twist to a sintering cycle. The copper diffuses more rapidly into the nickel than nickel into copper — in fact, the copper wires were consumed and the nickel wires grew!

**Commercial Considerations** — R. Talmage, powder metallurgy consultant of New Canaan, Conn., discussed some primary considerations in the design and use of commercial products. He stated that powder metal materials potentially can surpass cast materials in quality, since they eliminate inclusions and piping, and require less manpower and equipment. Although porosity is considered a disadvantage for cast metals, it is used for its specific effects in a powder metallurgy part. He listed several requirements for the powder metallurgy industry:

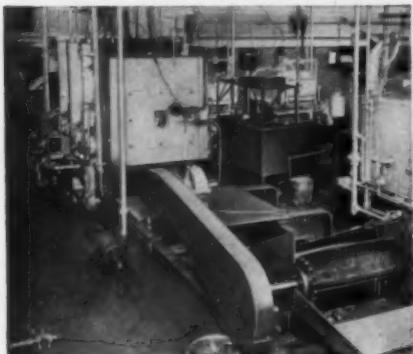
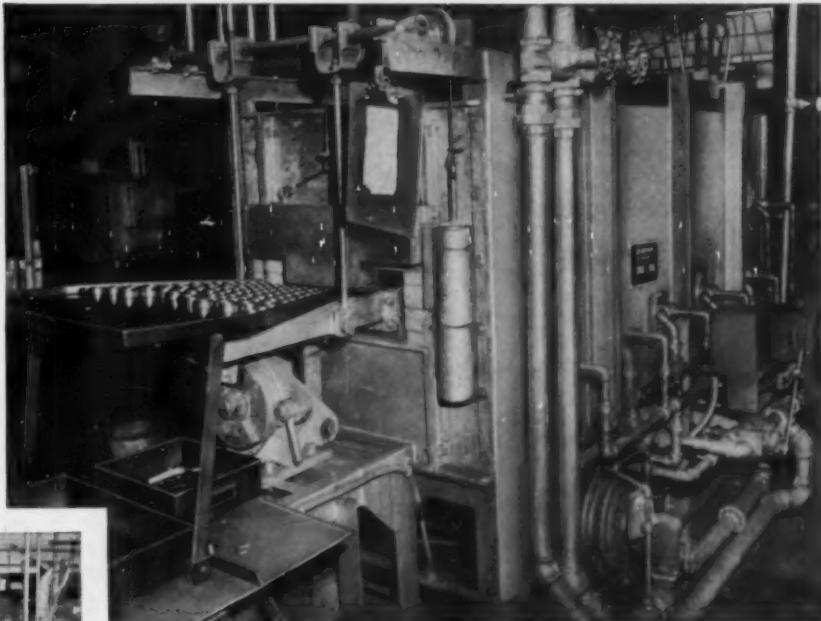
1. Manufacture of properly sintered and designed parts for competition with cast steel.
2. Data on density and strength to be pooled by all competitive fabricators.
3. Cooperation of powder metal fabricators to set up workable specifications.
4. Distribution of performance tests by users.
5. Specification by fabricators of density and strength.
6. Full publicity by fabricators as to the variation of properties with fabrication conditions.
7. Appreciation of the problems of fabrication by the purchaser.
8. Improved specifications for high-carbon, high-copper ferrous parts.
9. Education of users as to the properties and uses of sintered steel.

It seems that the powder metallurgy industry has its work cut out! ☺

## Lesson in low heat-hour cost at NORMA-HOFFMANN

(1) Charge end of Stewart Reciprocating Hearth Furnace showing bearing races entering. Average output is 125 pounds per hour. S.A.E. 52100 steel is hardened to 65-66 Rockwell C. Nichrome hearth casting has been operating over 9 years.

(2) At discharge end, ball races are dropped into conveyor tank and quenched from 1540-1550 degrees.



## NICHROME\* Hearth Casting **STILL ON THE**

## **JOB AFTER 67,392 HOURS-9 YEARS!**

In maintaining low heat-hour costs at Norma-Hoffmann Bearings Corp.,<sup>†</sup> the extraordinary long life of Nichrome castings is the most important factor. The record speaks for itself.

In 1940 Norma-Hoffmann placed their first Sunbeam Stewart Reciprocating Hearth Furnace into 24 hour, 6 days per week, operation for heat-treating ball bearing races and rollers.

It wasn't until 55,641 hours (7 years) of this all-out production that the Nichrome hearth casting was changed. 67,392 hours (9 years) later it is still on the job—working as well as it did when first installed.

For Nichrome, performance like this is not unusual. It explains why, in plant after plant where Nichrome castings pile up outstanding records like this, the *heat-hour cost* of Nichrome is well below any other alloy you might be tempted to buy because of somewhat lower initial price.

And in designing special long life heat-treating equipment, Driver-Harris has priceless experience—40 years of it. So, for the most durable heat-resistant alloys and the most valuable engineering help obtainable anywhere, you would be wise to consult with us.

<sup>†</sup>Stamford, Connecticut

<sup>®</sup>T.M. Reg. U.S. Pat. Off.

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is manufactured  
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# Personal Mention



Allison Butts

After 41 years as a teacher at Lehigh University, PROF. ALLISON BUTTS  retired last month.

Receiving his bachelor of arts degree from Princeton University (1911), he continued his technical studies at Massachusetts Institute of Technology and obtained his bachelor of science degree in mining engineering in 1913. After three years as a research chemist at the United States Metals Refinery Co., Carteret, N.J., Butts joined the faculty of Lehigh University as an instructor in metallurgy; he was made an assistant professor four years later, rising to full professor in 1939. Named head of the department of metallurgy in 1952, Professor Butts relinquished his administrative duties in 1956 to devote full time to teaching, research and writing.

Professor Butts has been active as an editor and author, in addition to his teaching duties. He was an associate editor of *The Mineral Industry* from 1916 to 1927, a special editor for Webster's International Dictionary and for 26 years was an abstractor for *Chemical Abstracts*; in the field of technical literature, he has written several books and edited several more.

His society memberships include the A.I.M.E. and the British Institute of Metals.

Richard A. Papa  has become a member of the material and process section of Westinghouse Electric Corp., Springfield, Mass. He was formerly associated with the Lycoming Div. of Avco Mfg. Co., Stratford, Conn.

Irwin L. Tunis  is studying law at Tulane University, and upon completion of his studies, he intends to enter the field of patent law.

Stanley J. Hanson  is now Detroit district manager for Wheelco Instrument Div. of Barber-Colman Co., Rockford, Ill. Before moving to Detroit, he was with the company's Chicago office as a sales engineer.

Joseph F. Duwell  has completed his work toward a bachelor of science degree in metallurgical engineering and is now employed by Pelton Steel Castings Co., Milwaukee, Wis.

Herbert M. Frazier  has retired from the Navy Department Bureau of Ordnance.

James F. Traa  recently was promoted from assistant manager, Detroit district sales, to manager of sales, Chicago district, for the U.S. Steel Corp.

Charles D. Preusch  has assumed new responsibilities as chief metallurgist of the Spaulding Works of the Crucible Steel Co. of America in Harrison, N.J. Since joining Crucible in 1940, Mr. Preusch has served as a metallurgist in the company's Eastern Research Laboratory, metallurgist in the metallurgical laboratory and the melting department of the Harrison plant, and recently as foundry metallurgist.

H. Charles Yaeger  has been named plant manager of the new Vickers, Inc. plant at Jackson, Miss. Mr. Yaeger has been associated with aircraft engine builders and aircraft accessory manufacturers for 20 years.

Robert R. Miller , president of Precision Metalsmiths, Inc., Cleveland, was honored for his contribution to the Investment Casting Institute at the Institute's annual spring meeting in Chicago. Mr. Miller's award was made "for his many contributions to the Institute and the industry", and specifically for his direction of the ICI Design Manual which was published recently by the Institute.

Bernard J. Conway  has been named sales engineer and manager of the Philadelphia district of General Alloys Co., Boston. Mr. Conway was formerly sales and service engineer with John P. Clark Co., Glenside, Pa., a partner in the Olney Distributing Co., Philadelphia, and superintendent in charge of heat treating and finishing operations with Procter Electric Co., Philadelphia.

Ralph R. Sorber  is now project manager of ten second shift departments in Building 46 and 47 of the Endicott (N.Y.) plant of International Business Machines Corp. Joining IBM in 1950 as a heat treat operator, Mr. Sorber has served as inspector in that department, heat treat technician, and more recently as manager of the heat treat department.

Robert C. Kuhn  was named to the newly created position of east central regional sales manager of Crucible Steel Co. of America, Pittsburgh, with offices in Cleveland. Mr. Kuhn will be responsible for sales activities at the company's branch offices in Cleveland, Detroit, Cincinnati, Pittsburgh, Buffalo and Grand Rapids. Mr. Kuhn, who joined Crucible in 1943, was Cleveland branch manager until his appointment.

Andrew Hlivka  has joined the manufacturing department of the National Supply Co., Pittsburgh, as a staff engineer. Mr. Hlivka formerly served with the National Cylinder Gas Co., Chicago, for 20 years, rising to the position of supervisor of steel mill service.

# FAHRITE

HEAT AND CORROSION *Alloys*



## CENTRIFUGALLY-CAST TUBES



Centrifugally-cast  
Fahrite alloy tubes for  
roller shaft assemblies,  
tubular furnace hearths  
and radiant heating  
installations. Many sizes of Fahrite  
tubes can be centrifugally-cast  
from Ohio Steel's permanent mold equipment.  
Fahrite U-bends also are available for  
use with tubes in radiant heating  
installations. Centrifugally-cast tubes are  
available in many grades of Fahrite to meet  
your exact operating conditions.



THE OHIO STEEL FOUNDRY CO.  
SPRINGFIELD, OHIO

Plants at Springfield and Lima, Ohio

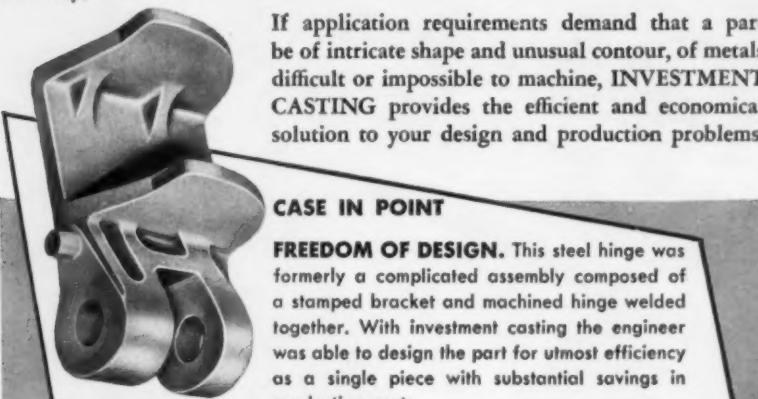
OS



## Originality and economy are compatible . . . at **ARWOOD**

**INVESTMENT CASTING** is one of the few production processes that caters to the creativity of a design engineer. No more frustration caused by the limitations of conventional processes. And . . . without sacrificing production economy, either!

If application requirements demand that a part be of intricate shape and unusual contour, of metals difficult or impossible to machine, **INVESTMENT CASTING** provides the efficient and economical solution to your design and production problems.



### CASE IN POINT

**FREEDOM OF DESIGN.** This steel hinge was formerly a complicated assembly composed of a stamped bracket and machined hinge welded together. With investment casting the engineer was able to design the part for utmost efficiency as a single piece with substantial savings in production costs.

### A New Service for YOU!

ARWOOD offers a complete finish-machining service, for your convenience. All Arwood plants can now furnish finish-machined castings to your specifications.

For complete information on Investment Casting and the name of your nearest ARWOOD Engineering Representative, write TODAY to:

# ARWOOD

**ARWOOD PRECISION CASTING CORP.**  
319 West 44th Street, New York 36, N. Y.

PLANTS: Brooklyn, N. Y.—Groton, Conn.—Tilton, N. H.—Los Angeles, Calif.  
"PIONEERS IN INVESTMENT CASTING"

## Personals . . .

**H. Gordon Poole** , head of the department of metallurgical engineering at the Colorado School of Mines, has taken a post as research and development consultant for the Albany, Ore., operations of the Oregon Metallurgical Corp. Professor Poole taught at the University of Washington and Case Institute of Technology before joining the faculty of the Colorado School of Mines. In addition to his present duties, he is also supervising research work for the Naval Bureau of Ordnance.

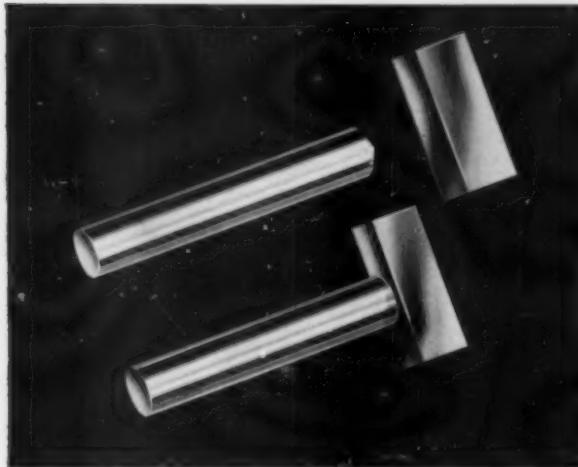
**Alexander J. Yorgiadis** has been chosen to head a new department at the Electronics and Instrumentation Div. of Baldwin-Lima-Hamilton Corp. in Waltham, Mass. The new department, to be known as the Dynamics Products Group, will design and develop equipment for measuring shock, vibration and acceleration. Mr. Yorgiadis will be product manager and chief engineer of this group. Until recently he was a chief development engineer with the Ivy Co., Norwalk, Conn., and prior to that was affiliated with the Sandia Corp., Albuquerque, N.M.

**Clarence P. Sander** , was elected president of the American Welding Society for 1957-58 at the Society's annual meeting in Philadelphia this spring. Mr. Sander, who previously served as first vice-president of the Society, is general superintendent, Vernon plant, Consolidated Western Steel Div., U.S. Steel Corp., Los Angeles. At the same meeting, **O. B. J. Fraser** , assistant manager of the development and research division, International Nickel Co., New York, was awarded honorary membership in the Society. The award was made to Mr. Fraser, formerly president of the Society, for exceptional achievements, specifically in connection with the joining of nickel and nickel alloys. **Fred Plummer** , was named as winner of the Samuel Wylie Miller Memorial Award for his outstanding contributions in the application of welding to storage tanks and to the advancement of engineering technology in the shop and field fabrication of welded structures. He is director of engineering, Hammond Iron Works, Warren, Pa.

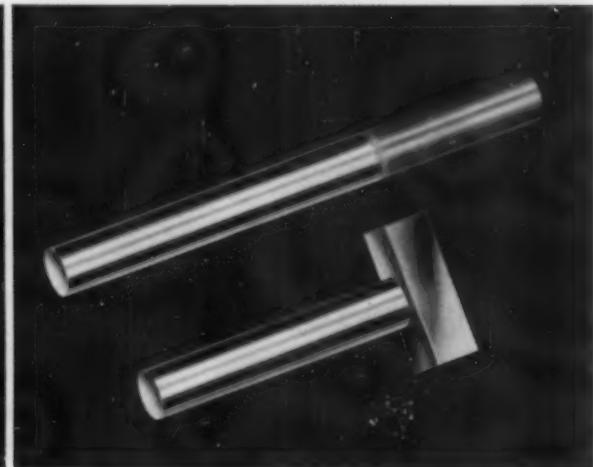


# G.R.S. Guts Costs 65%

*with TOCCO\* Induction Heating*



Old Method—headpieces and shanks were butt-welded after shanks were pointed and both parts sandblasted.



New Method—relay cores are formed from barstock heated by TOCCO Induction Heating. No sandblasting or welding is required.

● When General Railway Signal Company converted from butt-welding to TOCCO Induction Heating to form this relay core, they not only produced a better product, faster—but saved money doing it.

**Faster Production**—A 75 kw, 10,000 cycle TOCCO unit heats  $4\frac{1}{8}$ " of this  $9\frac{1}{8}$ " long,  $\frac{3}{4}$ " diameter silicon steel bar to 2100° F. for upsetting magnetic relay cores. 40 kw of high-frequency energy is used, producing 250 pieces per hour—nearly three times the production achieved by their former method.

**Lower Cost**—Formerly G.R.S. cut separate shanks and rectangular headpieces for this relay core. The shanks had to be pointed and both pieces sandblasted prior to butt-welding. Heating the blanks for forging with TOCCO saves nearly two-thirds the cost of this former method.

**TOCCO is Flexible**—The part shown is only one of nearly 300 that G.R.S. is heating for forging with

TOCCO. Production runs vary from 15 to over 50,000 pieces.

It may pay *you* to investigate TOCCO as a sound method of improving product quality, increasing production and reducing costs.



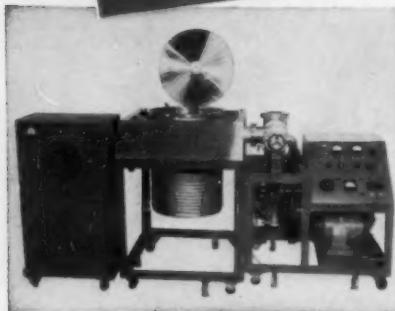
**Mail Coupon Today—NEW FREE Bulletin**

The Ohio Crankshaft Co. • Dept: R-7, Cleveland 5, Ohio  
Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

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Position \_\_\_\_\_  
Company \_\_\_\_\_  
Address \_\_\_\_\_  
City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_

# VACUUM METALLURGY

BY THE  
POUND



® **Kinney**

## STANDARD LABORATORY VACUUM FURNACES

These universal furnaces enable the metallurgist to investigate problems in melting, pouring, sintering and heat treating under vacuum. Shown at the left is an economical and versatile unit featuring 7½ KVA Packaged Power Unit and 4" Diffusion Pump. A second, very popular model, the KINNEY F-9, will handle up to 5 pounds of steel and is capable of doing all of the usual laboratory vacuum operations which require heating of metals in vacuum, except arc melting.

BY THE  
TON



® **Kinney**

## CUSTOM BUILT VACUUM FURNACES

High capacity Vacuum Furnaces for Stainless Steel, alloys and other metals. Shown at the right is a high-speed, high-capacity pumping system which is automatic in operation and is remotely controlled by a graphic panel. The assembly illustrated is for use with a 500 lb. melting and casting furnace. Other equipment for limited or high production is also available, built to meet the individual requirement. KINNEY engineering offers the metallurgist advanced designs in Vacuum Degassers, Vacuum Heat Treating Ovens, Evaporators and Vacuum Testing Equipment, all featuring the famous KINNEY Rotary Piston and Mechanical Booster Pumps.

**KINNEY** MFG. DIVISION  
THE NEW YORK AIR BRAKE COMPANY

3584G WASHINGTON STREET • BOSTON 30 • MASS.



Kindly send me FREE copy of KINNEY Bulletins on

High Vacuum Pumps  
 High Vacuum Systems

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### WRITE:

for information on  
KINNEY High Vacuum  
Pumping Equipment  
and Bulletins on  
Complete High  
Vacuum Systems

## Personals . . .

Keith Bock , after receiving his master's degree in metallurgy from Purdue University in January, accepted a position as metallurgical engineer with the Kaiser Steel Corp., Fontana, Calif.

Edward J. Stoyack , a recent graduate of the University of Michigan with a bachelor's degree in metallurgical engineering and chemical engineering, is now a research engineer with North American Aviation, Inc., Los Angeles.

Donald N. Frey , a recent graduate of the University of Michigan with a bachelor's degree in metallurgical engineering and chemical engineering, is now a research engineer with North American Aviation, Inc., Los Angeles.

Walter G. Marz , has accepted the post of technical services supervisor with the Metals Research and Development Corp., Exeter, Pa., a new facility established to serve industry and the U.S. Atomic Energy Commission. Mr. Marz was formerly employed by Glenn L. Martin Co., Baltimore.

D. A. Thompson , a technician in the engineering department of the University of Manitoba for 12 years, has been a plant metallurgist at the Manitoba Foundries & Steel Ltd., a subsidiary of Vulcan Iron & Engineering Ltd., Winnipeg, Canada, for the past year and a half.

William B. Scott , has left his post as general superintendent of foundries at the Baldwin-Lima-Hamilton Corp., Eddystone, Pa., to accept the post of assistant to the president, in charge of research and development, for the Janney Cylinder Co., Philadelphia.

K. J. Oswalt , has been transferred from the Chicago Heights, Ill., plant of the American Manganese Steel Div. of American Brake Shoe Co. to the Los Angeles plant. The transfer also entailed a change of position from castings metallurgist to metallurgist for the division West Coast plants at Los Angeles and Oakland, Calif.

W. B. Learned , was recently appointed manager of the New Haven branch of Crucible Steel Co. of America. His former position was assistant manager.



# Composite Alloy Radiant Tube Assemblies!

Critical section of the radiant tube assembly is cast from NA22H to provide greater heat resistance. The balance of the assembly is cast from an alloy of the proper grade for optimum service in individual furnaces.

## Provide greatly increased tube life

The new National Alloy radiant tube assembly is designed and built for maximum service under the punishing conditions found in all types of radiant tube furnaces. Its special construction puts alloys with greater heat resisting properties into critical sections of the assembly.

In pilot installations this added ruggedness has resulted in two to three times the tube life previously experienced. This fresh approach in meeting the strict requirements imposed by higher heat treating tempera-

tures results from special know-how and infinite care in construction.

As the leading specialist in high temperature alloy castings for radiant tube furnaces, National Alloy has had unique experience in dealing with the problems brought about by elevated temperatures, and the men and machines to give you the practical answer. For the full story on how composite alloy radiant tubes may improve your heat treating operations, contact National Alloy today. No obligation of course.



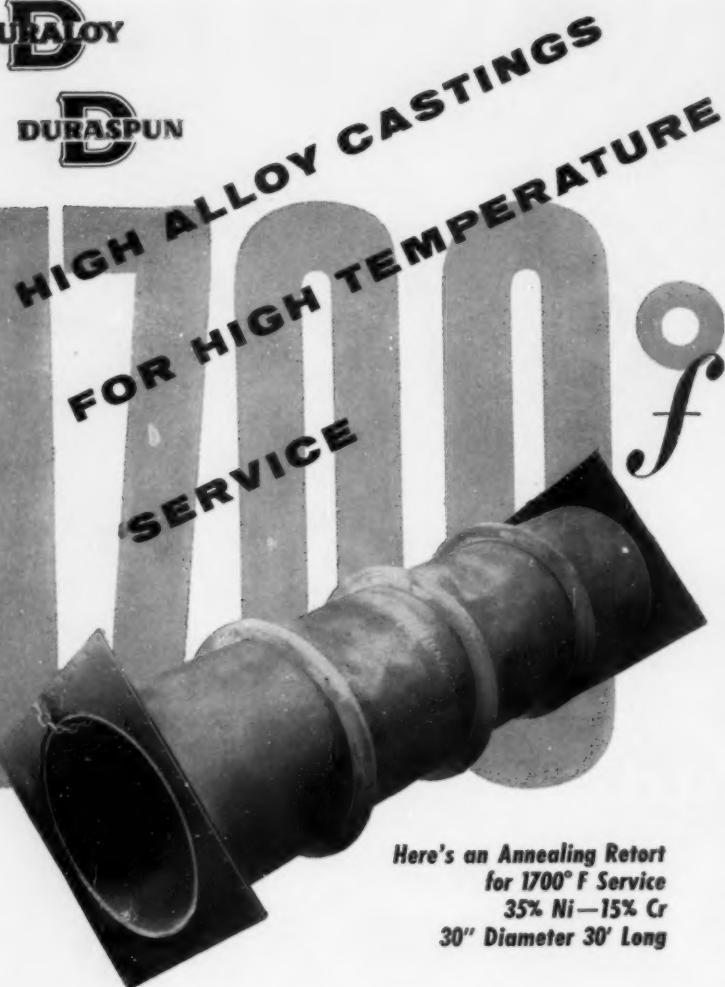
## BLAW-KNOX COMPANY

*National Alloy Division  
Pittsburgh 38, Pennsylvania*



**DURALOY**

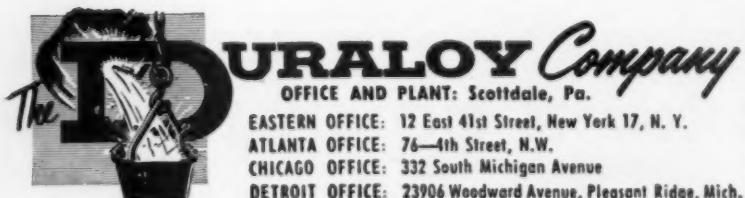
**DURASPIN**



Duraloy is the place to come for high alloy castings—for high temperature service, for highly corrosive service. Castings to your specifications are a Duraloy specialty.

We are equipped to do large and small work. We can turn out single static castings of 7 tons or more and single centrifugal castings up to about 4½ tons. On your next high alloy casting job, check with Duraloy!

**Send for Bulletin No. 3354-G**



## Personals . . .

Andrew J. Snow  has been promoted to sales manager of the furnace and oven division of W. S. Rockwell Co., Fairfield, Conn. A mechanical engineering graduate of Massachusetts Institute of Technology, Mr. Snow came to the company after several years as a plant engineer with U.S. Rubber Co. and industrial engineer with Chase Brass & Copper Co.

Robert C. Humphrey  was recently promoted to the position of assistant manager of the Westinghouse Electric Corp.'s metals plant at Blairsville, Pa. Prior to this promotion, he held the post of superintendent of manufacturing, alloy department, at the metals plant.

Paul E. Busby  has been named director of research for the Heppenstall Co., Pittsburgh. Mr. Busby joined the company in 1955 as a research assistant and was made assistant director of research a year later.

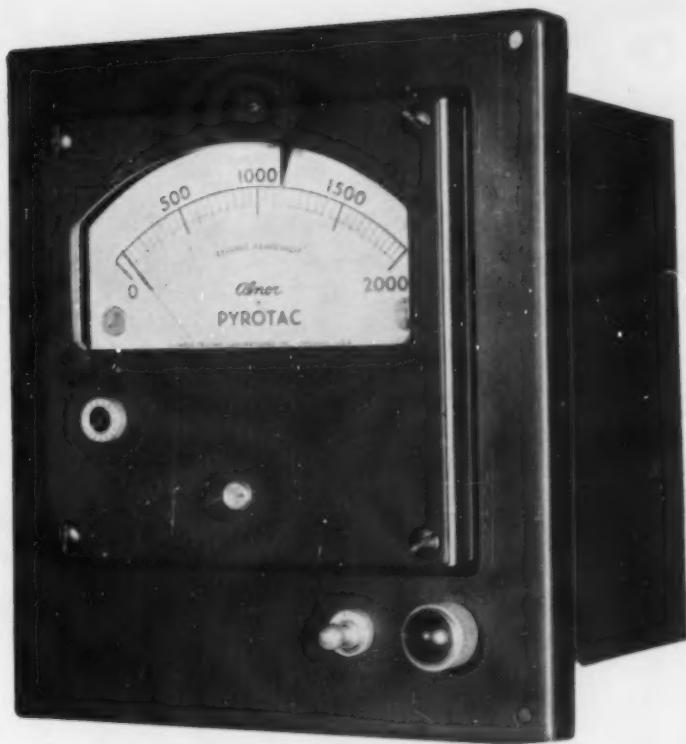
Harry L. Gaddis  has been promoted to superintendent of the railroad wheel works department of the Butler (Pa.) Works, Armco Steel Corp., Middletown, Ohio. Since joining Armco in 1939, he has served in various capacities in the research division, and in 1952 was transferred to the Butler works as turn foreman in the pressing and rolling section of the wheel works. He was named assistant superintendent in 1955.

Raymond K. Dykema, Jr.,  of the Detroit sales office of the stainless steel division of Jones & Laughlin Steel Corp., has been named Cleveland district manager of sales for the division.

Rowland A. Tisdale  and Norman F. Tisdale, Jr.,  have formed a new company known as Canam Metallurgical Sales Co. in Pittsburgh. Rowland Tisdale was formerly at the Homestead District Works of the U.S. Steel Corp., while his brother, Norman, was associated with the Molybdenum Corp. of America.

Jack B. Bennett  has joined North American Aviation, Inc., Los Angeles, as a research engineer, following seven years with the Colorado Fuel and Iron Corp.

# PYROTAC



## Automatic protection against temperature damage

Just as a fuse protects electrical circuits against overloads, the Alnor Pyrotac automatically protects furnaces, kilns and other heating equipment against damage due to excessive temperatures.

This low-cost, easily installed instrument can be added to any automatic or manually controlled equipment and give continuous protection...safeguard your investment in equipment, controls and material in process.

Highest Alnor quality throughout, the Pyrotac features Alnico magnet, double air-gap movement that is standard in all Alnor pyrometers...laboratory precision...industrial ruggedness which assures top reliability.

Write today for complete details on the Pyrotac, available in eight scale ranges from 0-600° F. and 0-3000° F. Ask for Bulletin 2002. Illinois Testing Laboratories, Inc., Room 523, 420 North LaSalle St., Chicago 10, Illinois.



ALNOR PRECISION INSTRUMENTS  
FOR EVERY INDUSTRY



All the proven advantages of DOW'S top quality controlled atmosphere, furnaces with built-in atmosphere generators . . . PLUS time saving automation in one compact, efficient package.

This new furnace pre-conditions, loads and unloads the work chamber, quenches the charge and discharges the finished work without operator handling.

No time loss, no guessing, no human error . . . every load identically processed and handled.

Write for detailed literature.

**DOW FURNACE COMPANY**

12045 Woodbine Ave., Detroit 28, Mich.  
Phone: KEnwood 2-9100

**First** WITH  
MECHANIZED, BATCH-  
TYPE, CONTROLLED  
ATMOSPHERE FURNACES

## Personals . . .

Leon J. Printz  $\ominus$  has been named to assist James K. Nyburg  $\ominus$  in the expanded sales and customer metallurgical service program of the metal powder division of Republic Steel Corp., Toledo, Ohio. Mr. Printz has a background of 24 years experience in powder metallurgy, and prior to his Republic appointment, was chief metallurgist for research and development of powdered metals for the Amplex Div. of Chrysler Corp., Detroit. As manager of sales for the division, Mr. Nyburg has directed the sales of powdered metals for the last year.

John J. Green  $\ominus$  has been assigned to the newly created position of manager, wrought steel service, for the Vanadium Corp. of America, Pittsburgh. Formerly employed by Universal-Cyclops Steel Corp., he joined Vanadium in 1955 as service engineer.

Lloyd A. Cook  $\ominus$  is now manager of Ravens-Metal Products, Inc., Ravenswood, W.Va. Mr. Cook has had more than 11 years of experience in the metal fabricating industry, primarily with Aluminum Laboratories, Ltd., Kingston, Ont., Canada, and in the Kaiser Aluminum & Chemical Corp. department of metallurgical research, where he was in charge of all welding and joining research and development work. The chief engineer of Ravens-Metal Products is Donald G. Shafer  $\ominus$ . He was associated with Kaiser Aluminum & Chemical Corp. as supervisor of solid phase bonding research before assuming his present post.

B. R. Nijhawan has been appointed director of the National Metallurgical Laboratory, Council of Scientific and Industrial Research, Jamshedpur, India.

John B. Girdler  $\ominus$  has been assigned the post of commercial vice-president of sales, a newly created position in the sales department of Vanadium Corp. of America, New York. Mr. Girdler has served the company in various sales capacities since 1935, including regional manager in Pittsburgh and sales manager in the New York office. He last held the position of assistant vice-president and general manager of sales.



**Are you  
interested in  
ULTRA HIGH PURITY  
ARGON**

*...in quantity...at minimum price?*

Ultra High Purity Argon—we at Air Products call it U.H.P. Argon—has a purity in excess of 99.995% . . . reduces the danger of undesirable oxidation in inert gas shielded arc welding more effectively than commercial grade argon. This "research" grade gas supplied by Air Products in commercial quantities affords superior control of the weld pool and of the arc . . . less clouding and a better view.

Produced by Air Products' low-temperature processing plants, U.H.P. Argon is also used as an inert protecting atmosphere in the sintering of metal powders such as titanium and zirconium . . . drawing of tungsten wire and filaments . . . fabrication of high-speed, metal-cutting tools . . . reduction of titanium and zirconium tetrachloride with magnesium.

We produce U.H.P. Argon and other industrial gases such as oxygen, nitrogen and hydrogen. We supply these gases in practically any combination of states, purities and pressures. We design, manufacture, erect and operate low-temperature processing equipment: package, tonnage and custom-built industrial gas separation, liquefaction and purification systems.

Have you a use for U.H.P. Argon . . . at competitive prices and in from cylinder to tank car quantities? Let us know if you're interested, and what your requirements may be. Air Products, Incorporated, P.O. Box 538, Allentown, Pa.

***Air Products***  
...INCORPORATED

# These Oakite shortcuts speed your metal cleaning

## 1. Cleaning and rustproofing —in one washing operation.

Oakite Composition No. 98 (used cold or hot in one-stage or two-stage washing machines) quickly removes cutting oils and chips and leaves a thin film that protects steel against rusting between operations or during temporary storage.

Excellent for cleaning before inspection: the metal is cool for immediate handling and the film (too thin to affect measurements) prevents finger prints from corroding highly finished surfaces.

One auto manufacturer uses No. 98 in seven plants for cleaning and rustproofing brake cylinders, camshafts, connecting rods, crankshafts, cylinder heads, flywheels, push rods, tappets, wrist pins, etc.

## 2. Stripping pigmented paints—with no need for pickling before repainting.

Oakite Rustrripper saves money in paint shops by doing a complete stripping job in one operation. It eliminates extra pickling and neutralizing to remove the metallic pigments, phosphate coatings and rust that prevent successful repainting.

A television manufacturer says "We formerly took 25 minutes to strip rejected cabinets, then had to pickle to remove tarnished phosphate coatings. Today 10 minutes in Rustrripper strips the same cabinet so bright and clean you can't tell it from new. Eliminates pickle, neutralize and rinses."

An auto parts maker uses Rustrripper for continuous conveyor line stripping. "Cycle of 1 minute and 50 seconds works like a charm stripping paint and incidental rust from rejects and hooks."

**FREE** For full information write for booklets:

1. "For Power Washers—Oakite Composition No. 98" or
2. "Here's the best shortcut in the field of organic finishing."

Address Oakite Products, Inc., 30H Rector St., New York 6, N. Y.

Technical Service Representatives in Principal Cities of U.S. and Canada



Export Division  
Cable Address: Oakite

## Personals . . .

**A. K. Eikum** is now an engineer in mechanical metallurgy at the General Electric Knolls Atomic Power Laboratory, Schenectady, N.Y. A graduate of the State College of Washington, Mr. Eikum joined the General Electric CheMet Program in July 1956.

**A. Simkovich**, after receiving his master of science degree in metallurgy from Pennsylvania State University a year ago, was commissioned as an ensign in the U.S. Navy. He is now assigned to Project Vanguard, the earth satellite project at the Naval Research Laboratory, Washington, D.C., as a mechanical aeronautical engineer, assigned to the engineering consultant branch of the earth satellite section.

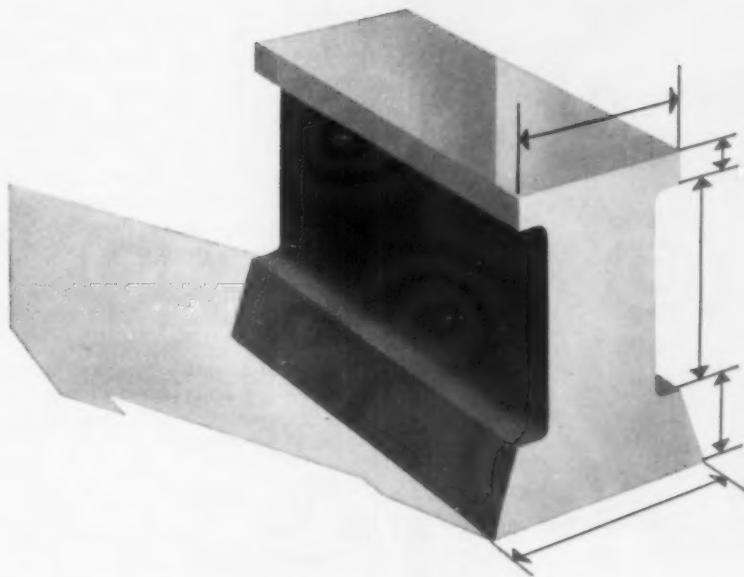
**J. F. Ednie** has accepted the post of chief metallurgist for the National Precision Casting Corp., Clifton Heights, Pa., recently acquired by the Beryllium Corp. Mr. Ednie will have charge of quality control, laboratories and development programs. Before coming to National Precision, he was a metallurgical engineer for Vertol Aircraft Corp., Morton, Pa.

**Bertrand S. Norris** is now serving as an assistant to the chief engineer of the industrial division of the York Div., Borg Warner Corp., York, Pa. He was a metallurgist in the research laboratory of the division, until that department was discontinued recently.

**Thomas G. Kuzma** has been appointed Detroit district manager of sales for the Rotary Electric Steel Co., Detroit.

Two newly created positions with Crucible Steel Co. of America have been filled by **William E. Pennington** and **Edward K. Streeter**. Mr. Pennington is eastern regional sales manager, with headquarters in New York, while Mr. Streeter serves as midwestern regional sales manager, with headquarters in Chicago. Joining Crucible at the Pittsburgh sales branch, Mr. Pennington has served in various sales capacities, last holding the post of eastern area manager. Mr. Streeter, who began his career with Crucible in 1929, was Chicago sales branch manager until this appointment.

# Cost per clamp cut from \$1.06 to 58¢ with J&L hot extruded cold drawn section



This manufacturer cut the cost of contact clamps 45% by converting to J&L extruded sections. Previous cost of \$1.06 per part involved costly milling and scrap loss from cold drawn  $1\frac{1}{2}'' \times 1''$  flats.

Here's how extruded sections can cut your cost:

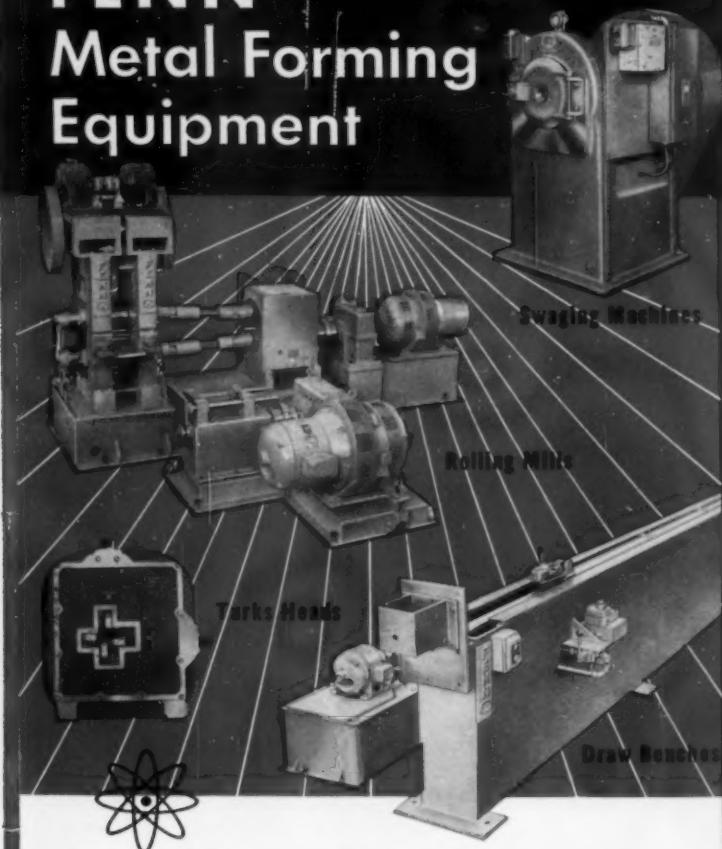
1. Eliminate machining and finishing operations.
2. Reduce scrap losses almost to zero.
3. Eliminate cost of casting and forging intricate sections.
4. Reduce inventories because extrusions are quickly available.

Investigate this new production technique for your shape profiles—within present limits of a design which can be inscribed in a three-inch circle. Available in a wide range of carbon and alloy steels. For specialty alloy and tool steels, submit inquiry. Get complete details by writing to the Jones & Laughlin Steel Corporation, Dept. 405, 3 Gateway Center, Pittsburgh 30, Pennsylvania.



**Jones & Laughlin**  
**STEEL** ... a great name in steel

# FENN Metal Forming Equipment



## Core of Your Nuclear Planning

**FENN PRECISION ROLLING MILLS** are made in a complete range of sizes and types for laboratory, pilot run and production. They are designed and built to meet the requirements of nuclear metallurgy, including the newest and toughest metals. They can be supplied in both vertical and horizontal types with complete instrumentation for remote control and hooding where necessary.

**FENN ROTARY SWAGING MACHINES** are the invaluable precision production tools for nuclear metal forming... hot or cold... without producing chips. A complete range of sizes with capacities from  $\frac{3}{8}$ " to 6" diameter. Models also available for internal reductions and with special length dies. Compact self-contained unit facilitates hooding.

**FENN DRAW BENCHES AND TURKS HEADS**—Fenn makes both hydraulic and mechanically actuated draw benches with capacities from 2,000 to 40,000 pounds pull. Variable drawing and return speeds to fit your specific requirements. Fenn Turks Heads, with infinite adjustment of rolls, are a valuable accessory to draw benches for producing almost limitless shapes in wire, rod, or tube.

For engineering services  
or literature, write  
NUCLEAR MACHINERY DIVISION

**FENN**

Fenn Manufacturing Co., 505 Fenn Road, Newington, Connecticut

## Personals . . .

**Glenn W. Geil**  a metallurgist at the National Bureau of Standards, Washington, D.C., has been awarded the Department of Commerce Silver Medal for Meritorious Service in recognition of his "exceptional achievement in physical metallurgy, particularly in studies relating to the deformation of metals at subzero temperatures". A member of the NBS staff since 1936, Mr. Geil is in the thermal metallurgy section, and plans and conducts research on the behavior of metals at both high and low temperatures.

**Richard E. Wiley**  has been transferred from the Bureau of Ships to the Office of Naval Research, Washington, D.C. He will serve as materials development coordinator in the Office of the Development Coordinator.

**Henry Present**  formerly associated with Crucible Steel Co. of America and Arwood Precision Casting Corp., has been appointed director of engineering and metallurgy of the Jelrus Precision Casting Corp., New York.

**John L. Merrill**  has been chosen to head the new Los Angeles sales office recently opened by the Riverside-Alloy Metal Div., H. K. Porter Co., Inc. Mr. Merrill, until recently associated with Eagle Metals Co., Seattle, Wash., is now district manager for the West Coast sales territory.

**Leo M. Elijah**  is now a project engineer in the parts division of Sylvania Electric Products, Inc., Warren, Pa. He formerly served as industrial metallurgist with the Ford Motor Co. of Canada Ltd.

**Alfred W. Sikes**  a retired Army colonel, was recently elected to a national honorary membership in the Construction Specifications Institute at the Institute's convention in Washington, D.C. Mr. Sikes founded the Chicago chapter of the Institute and served as its first president, 1952-54.

**Harold L. Gegel**  is serving in the U.S. Air Force at Wright-Patterson Air Force Base, Dayton, Ohio. He is assigned to the materials laboratory as a project engineer in the light metals section.

*This is the twenty-second of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.*

## Normalizing Alloy Steels

There are several forms of heat-treatment commonly employed in the processing of alloy steels. Each in its own way modifies the mechanical properties and structures of steel, and each is chosen with a definite objective in mind. The five usual forms of treatment are normalizing, annealing, spheroidize-annealing, quenching and tempering, and stress-relieving.

In this particular discussion, let us consider briefly the purposes and effects of normalizing.

Normalizing is an operation in which the steel is heated to approximately 100 deg F above the upper transformation range, then cooled in still or agitated air. The basic purpose is to refine the prior structure produced by variations in finishing temperatures encountered in rolling or forging. The structure resulting from normalizing, being more uniform, will help create improved mechanical properties when the steel is subsequently reheated, liquid-quenched, and tempered.

There are times when large steel parts (heavy forgings, for example) cannot be liquid-quenched because of their size. In cases of this nature, the heat-treatment must consist of single or multiple normalizing followed by tempering.

High-temperature normalizing is sometimes used for grain-coarsening low-carbon alloy steels to promote machinability. (In high-temperature normalizing, steel is heated to more than 100 deg F above the upper transformation range.) At times it is possible to machine a steel in the air-cooled condition, the governing

factor being the alloy content. However, the highly alloyed analyses may require annealing or tempering after normalizing, to decrease the hardness.

It is essential, when normalizing is employed, that free circulation of still or agitated air be provided. When air-cooling of individual bars or forgings is not practicable, the furnace charge should provide for some means of separation, such as racks or spacers.

If you would care to know more about normalizing, or any other phase of heat-treating, you are invited to consult with Bethlehem metallurgists. They have had long experience in such matters, and they know how each treating method affects the various alloy steels. They are always glad to give you any help you need.

And when next in the market, please remember that Bethlehem makes the full range of AISI standard alloy steels, as well as special-analysis steels and all carbon grades. We can furnish what you need.

*If you would like reprints of this series of advertisements from No. I through No. XX, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 20 subjects in the series are now available in a handy 36-page booklet, and we shall be glad to send you a free copy.*

BETHLEHEM STEEL COMPANY  
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation



**BETHLEHEM STEEL**

## Rare Earths on stream!



**Rare Earths** have remained rare only because of the exceptional technology required to process them. The best of this technology is everywhere evident in **HEAVY MINERALS** Co.'s new Chattanooga plant, now on stream.

Using domestic ores from its own mines, **HEAVY MINERALS** produces a complete line of rare earths for American industry.

The rare earths constitute a new industrial frontier. These 15 elements plus yttrium and thorium have so many versatile properties that almost all industries have a potential use for one or more of them.

**HEAVY MINERALS** supports its processing operations with a vigorous research and development program. Its personnel welcomes the chance to share its technology with rare earth users and potential users. We invite you to make use of our services and products.

*Send for free informative booklet*



## HEAVY MINERALS CO.

RARE EARTH CHEMICALS • THORIUM • HEAVY MINERALS

4000 NORTH HAWTHORNE STREET, CHATTANOOGA 8, TENN.  
SALES OFFICE: 261 MADISON AVENUE, NEW YORK 16, N. Y.

## Personals . . .

Robert F. Wilde  $\ominus$  joined the small aircraft engine department of General Electric Co. in Lynn, Mass., as a technical engineer in the Thomson Laboratory. He was formerly experimental metallurgist at the Allison Div., General Motors Corp., Indianapolis, Ind.

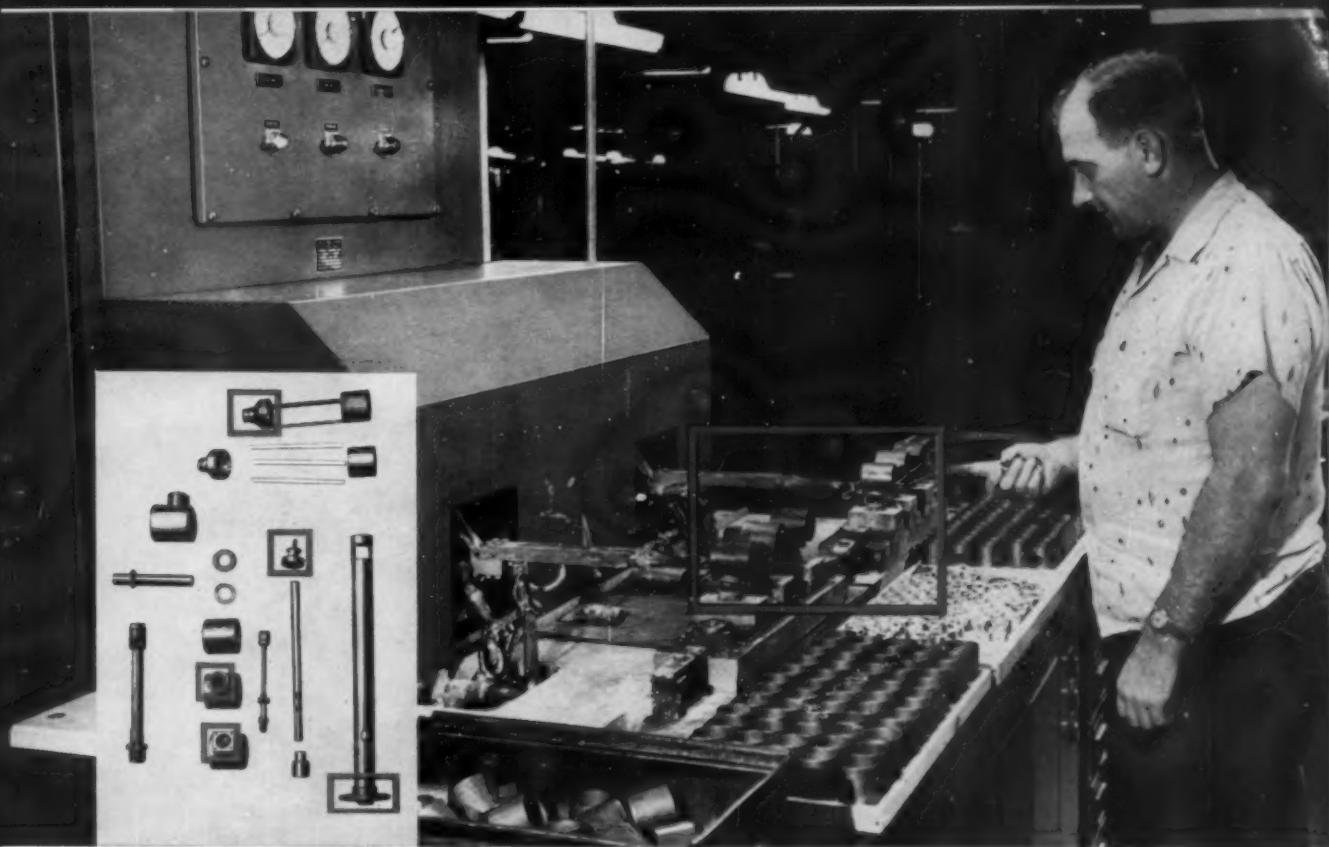
Loren W. Smith  $\ominus$  after 14 years as head of the metallurgy section of Cornell Aeronautical Laboratory, Buffalo, N.Y., accepted a position as assistant vice-president and director of research in charge of metallurgical development at the Symington-Gould Corp., Depew, N.Y. Mr. Smith is a past director of the Buffalo Chapter  $\ominus$ , and has served on several MAB panels, including the panel for the current titanium sheet rolling program.

Elwood D. Mairs  $\ominus$ , works manager of the Aluminum Co. of America's extrusion and tubing plant at Lafayette, Ind., has been selected by the Penn State Chapter  $\ominus$  as the 1957 recipient of the David Ford McFarland Award for Achievement in Metallurgy. The Award is an annual honor given to a metallurgy alumnus of Pennsylvania State University.

Aaron M. White  $\ominus$ , formerly group leader at the American Cyanamid Co., Stamford Research Laboratories, Stamford, Conn., is currently engaged in fabrication development at Nuclear Metals, Inc., Cambridge, Mass. Associated with American Cyanamid for 11 years, Mr. White was employed at Watertown Arsenal previously.

Harold J. Sering  $\ominus$  resigned from the U.S. Information Agency, international broadcasting service division, engineering department, to accept a position in the engineering department of Sargent & Lundy, design engineers, Chicago. During the last five years, Mr. Sering was stationed in Germany and Okinawa with the U.S.I.A.

E. F. Wohlers, Jr.,  $\ominus$  has been transferred from the special process group, production engineering, to materials engineering, engineering department, Minneapolis-Honeywell Aero Div., and has been assigned to the company's Florida operation.



AT HARTFORD MACHINE SCREW CO.—

## General Electric induction heaters braze 20 different parts, help cut rejects 91%

At Hartford Machine Screw Co., a General Electric electronic induction heater is used for brazing a wide variety of parts for electric-switch housings and jet engines.

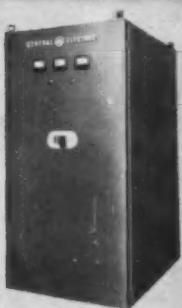
The General Electric unit takes on jobs ranging from  $\frac{1}{4}$ -inch to  $1\frac{1}{2}$ -inch tubing. After brazing, each part undergoes a regular 500-pound pressure test, and the aircraft work must pass radiographic inspection. With the General Electric induction heater, rejects have been reduced 91 per

cent, from 30-35 per cent to a maximum of two per cent.

"If we need another induction heater, it definitely will be a General Electric," says A. O. Haversat, plant engineer. "The output control alone makes it virtually a MUST. This feature is just what we need for our kind of production. It eliminates guesswork and costly human errors. And it cuts out excess tooling, while still assuring uniform brazing."

General Electric electronic induction heaters are available in four ratings— $7\frac{1}{2}$ , 15-, 25-, and 40-kw, with a choice of four different models in each rating. The four models provide various control combinations, so you can buy the one induction heater which best matches your production pattern from the standpoint of both rating and control.

For more information, send in the coupon below or contact your nearby General Electric Apparatus Sales Office.



Four models in each of four ratings:  $7\frac{1}{2}$  Kw, 15 Kw, 25 Kw, and 40 Kw.

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# Digests of Important Articles

## Rate of Graphitization of White Cast Iron

Digest of "Effect of Alloying Elements on the Rate of Graphitization of White Cast Iron", by M. A. Krishtal, *Metallovedenie i Obrabotka Metallov*, No. 5, 1956, p. 17-18.

THE INTRODUCTION of nodular cast iron has increased interest in the problem of graphitization. Although this paper deals with white cast iron, it offers interesting ideas about the nature of graphitization.

In a previous paper (digested in *Metal Progress*, November 1956, p. 182) Krishtal described graphitization experiments on special alloy cast irons. Rates of graphitization were determined by microscopic examination, and diffusion data of the type discussed below were obtained for the same alloys. It was found that the energies of activation for diffusion,  $Q$ , were about 40,000 cal. per mol, and so were much lower than those for self-diffusion of iron. Therefore it was concluded that the diffusion coefficients of vacancies were being measured. Comparison with previous data on the alloying elements in question suggested that the slower the rate of graphitization the larger the binding energy between iron and the alloying element and the smaller the difference in atomic diameter between the two.

In the present paper the author presents data on the effect of tungsten on graphitization of a 4% C, 1.2% Si cast iron. These data are summarized in the curves, and they supply strong support for the view that under most conditions the rate of graphitization,  $v$ , is limited by diffusion in the iron matrix rather than by the diffusion of carbon atoms. Thus, at tungsten contents below 0.6%, the rate of diffusion of vacancies in the austenite lattice is

lower than the rate of diffusion of carbon. In this range of tungsten contents the carbon can diffuse relatively freely but the necessary changes in the iron matrix are limited by the low rate of diffusion of vacancies. This is the condition in most cast irons.

The cast irons alloyed with 0.8 or 1.0% W were unusual in having the diffusion coefficient of carbon lower than that of the vacancies. In this range the impediment to graphitization is offered by the relatively low mobility of the carbon atoms.

Thus, this research demonstrates the dominant role played by diffusion processes in the graphitization of white cast iron.

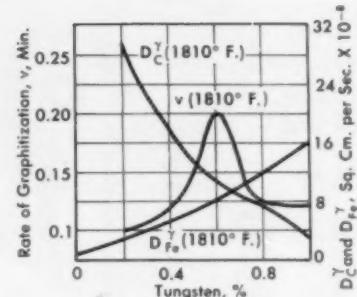
A. G. GUY

## New Iron-Powder Electrodes

Digest of "New Iron-Powder Electrodes and Their Applications", by Robert Shutt, *Welding Journal*, Vol. 35, December 1956, p. 1207-1213.

NEWEST PROGENY of the family of arc welding electrodes is the group containing substantial percentages of iron powder in the coating material. First introduced in this country about four years ago, they have been designed to produce better appearing welds with improved soundness and lower cost, the latter achieved through higher deposition rates and lower cleaning time.

Currently there are five basic types of iron-powder electrodes. First and most popular is E 6024, a high-rutile classification with the highest deposition rate of any of the hand electrodes. Next is E 6027, similar to the conventional E 6020 electrode, but less crack sensitive and having a higher deposition rate than the latter type. A third one



Relation Between the Rate of Graphitization,  $v$ , and the Diffusion Coefficients of Carbon and of Vacancies in Cast Iron Alloyed With Tungsten

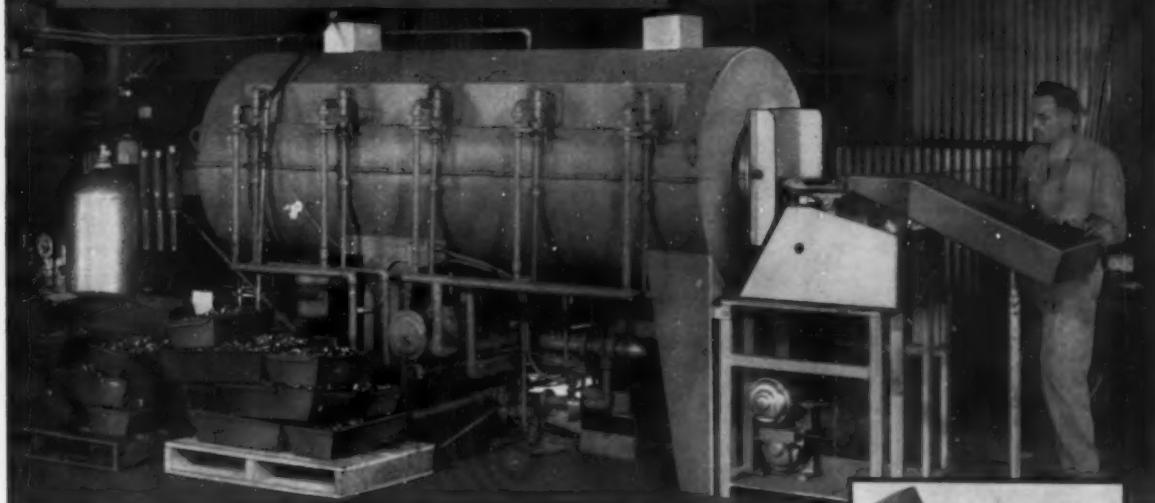
— an all-position E 6013 type electrode — is a relative newcomer. As against the conventional E 6013, the new electrode exhibits better slag removal, has smoother arc action with both a-c. and d-c., and has improved bead appearance. It is anticipated that it will be designated as E 6014.

A fourth is a new low-hydrogen electrode introduced in two types, one with 30% iron powder for all-position welding, the other with 50% iron powder for downhand welding. Advantages of the new electrode over conventional E 6015 and E 6016 include higher deposition rates, easier slag removal, and improved bead shape.

Crack-free welds in steels high in carbon, sulphur or phosphorus require care in the selection of the electrode. Heavier thicknesses also present a problem because quenching of the welds could result in cracks. Best electrode for these applications is the iron powder low-hydrogen Type E 6015 or E 6016, as previously mentioned.

Finally, there are now on the market iron-powder electrodes for buildup jobs in maintenance work. Conventional buildup electrodes are inclined to have "blustery" arc char-

"second helpings" for satisfied customers...



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Much of the credit must go to Valley's new Pacific Gas-fired Shaker Hearth Furnace. This furnace provided a combination of fast and economical operation with extremely uniform control of the work.

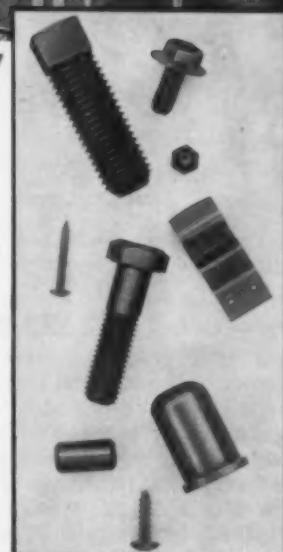
Rated at 500 pounds per hour, this new Pacific Furnace is used for Carbo-nitriding and scale-free neutral hardening. It permits maximum

hardness of all parts, and the 14" wide Inconel hearth with Pacific's exclusive shaker design allows a wide variety of work to be handled without damage to the parts.

According to Valley, their work comes out exceptionally clean, requiring only washing before delivery, and case depth is easily controlled due to Pacific's uniform-heating burner design.

This profitable performance is the reason Valley has installed two different types of Pacific Furnace, and has recently ordered a third!

For more information on a Pacific Furnace for your heat treating job, whatever it is, write today!



Typical of the wide range of parts handled in this furnace.



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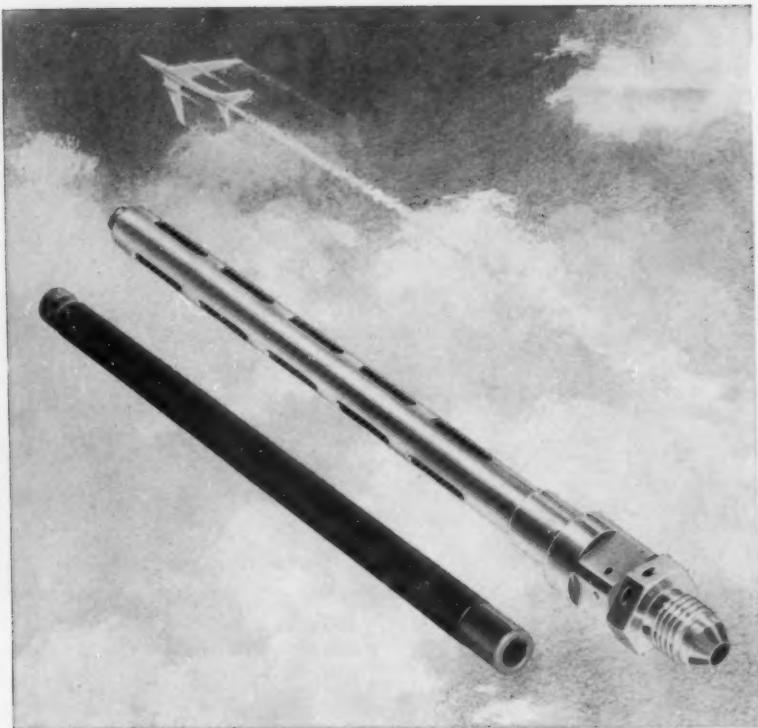
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# "FEVER THERMOMETER" for supersonic jets

In order to break sound barriers, jet engines must break some temperature barriers, too—which brings some real problems in material selection. Any thermostatic control in the jet stream must withstand temperatures of 2000° without significant change in properties and characteristics.

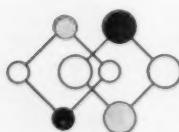
Faced with this problem, one of the world's leading designers and manufacturers of aircraft components and systems has made Kennametal\* a "Partner in Progress"—and has found an answer. For a vital part of the sensing element in a thermostat assembly, a small tube of Kentanium\* is used. This material, one of a big family of unusual

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Perhaps you have some new product in mind that is still on the drawing board for want of materials with the necessary properties to meet an unusual operating condition. If you need superior corrosion or erosion resistance, hardness, strength and stiffness, or resistance to elevated temperatures, chances are you can find the needed combination of properties in the Kennametal line. Just write, outlining your problem, to KENNAMETAL INC., Department CE, Latrobe, Pa.

\*Kentanium and Kennametal are the trademarks of a series of hard carbide alloys of tungsten, tungsten-titanium and tantalum.

C-3044A



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## New Electrodes . . .

acteristics and cause appreciable amount of spatter. The iron-powder coating overcomes these objections and makes possible fast deposition rates and easy slag removal.

When more weldments are designed and positioned for high-speed welding, more emphasis will be placed upon designing electrodes best suited to the work. When more purchasing specifications are based upon actual requirement of the applications, less time will be devoted to copying old products and more time to developing new ones which will assuredly produce better welding at more reasonable cost.

ARTHUR H. ALLEN

## Sprayed-On Hard Surfacing in the Petroleum Industry

Digest of "Longer Service Life Through Hard Surfacing for Petroleum Industry Equipment", by H. S. Gonser, *Welding Journal*, Vol. 35, September 1956, p. 890-894.

**I**N THE PETROLEUM industry to protect equipment against corrosion, abrasion, impact and galling, hard surfacing has been found to be most effective, because of the superior properties of the alloys so applied and the excellence of the welded or brazed bond. Tensile strength and ductility are not needed in the hard surface since these properties are provided by the base metal. The initial cost may be high because of the high cost of hard surfacing alloys. Sprayed-on hard surfacing also costs more than plating and metallizing, primarily because of the additional fusing operation required. (The powdered hard alloy is usually sprayed on the part to be coated, and fused in place with a torch.)

To demonstrate the superior resistance of a hard faced mild steel to that of hardened Type 410 stainless steel (Rockwell C-48) and flame hardened A.I.S.I. Type 4150 steel (Rockwell C-60), 3-in. diameter pump plungers of each material were tested in the laboratory by pumping a hot oxygenated brine containing sodium, calcium and magnesium chlorides at 750 psi.



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## Hard Surfacing . . .

pressure and 265 rpm. continuously during the test period. The hard facing nickel-base alloy, containing chromium boride, was sprayed and fused to mild steel. It served well for over 76 days, while the Type 410 steel became too scored and cracked for further service after 13 days, and the Type 4150 steel lasted only 2 days.

Chromium-plated compressor rods of Type 1035 steel normally last 6 months in hydrogen compressed to 800 psi., but hard surfaced rods last more than 18 months. In pumping dilute hydrofluoric acid, a standard plunger would last only 3 months. A hard surfaced coating 0.045 in. thick extended the life to more than a year.

Several newer applications of hard surfacing show considerable promise. One of them is the pro-

tection of reactor grid inserts or baffles in catalytic cracking units against abrasion by the catalyst. The hard alloy is applied by oxy-acetylene welding. Another is the prevention of galling in the internal threads between 60-ft. sucker-rod sections and their couplings.

Hard surfacing has now been found so useful in maintenance and reclamation work that it should find many effective applications in new equipment.

GEORGE F. COMSTOCK

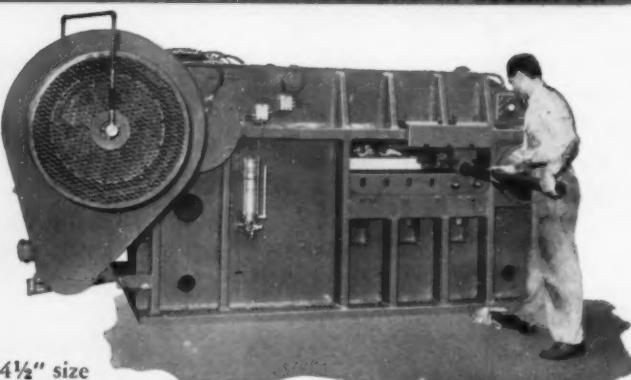
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## Case Hardening Processes in Perspective

Digest of "Modern Case-Hardening Processes", by P. F. Hancock, *Journal of the Birmingham Metallurgical Society*, Vol. 36, March 1956, p. 360-381.

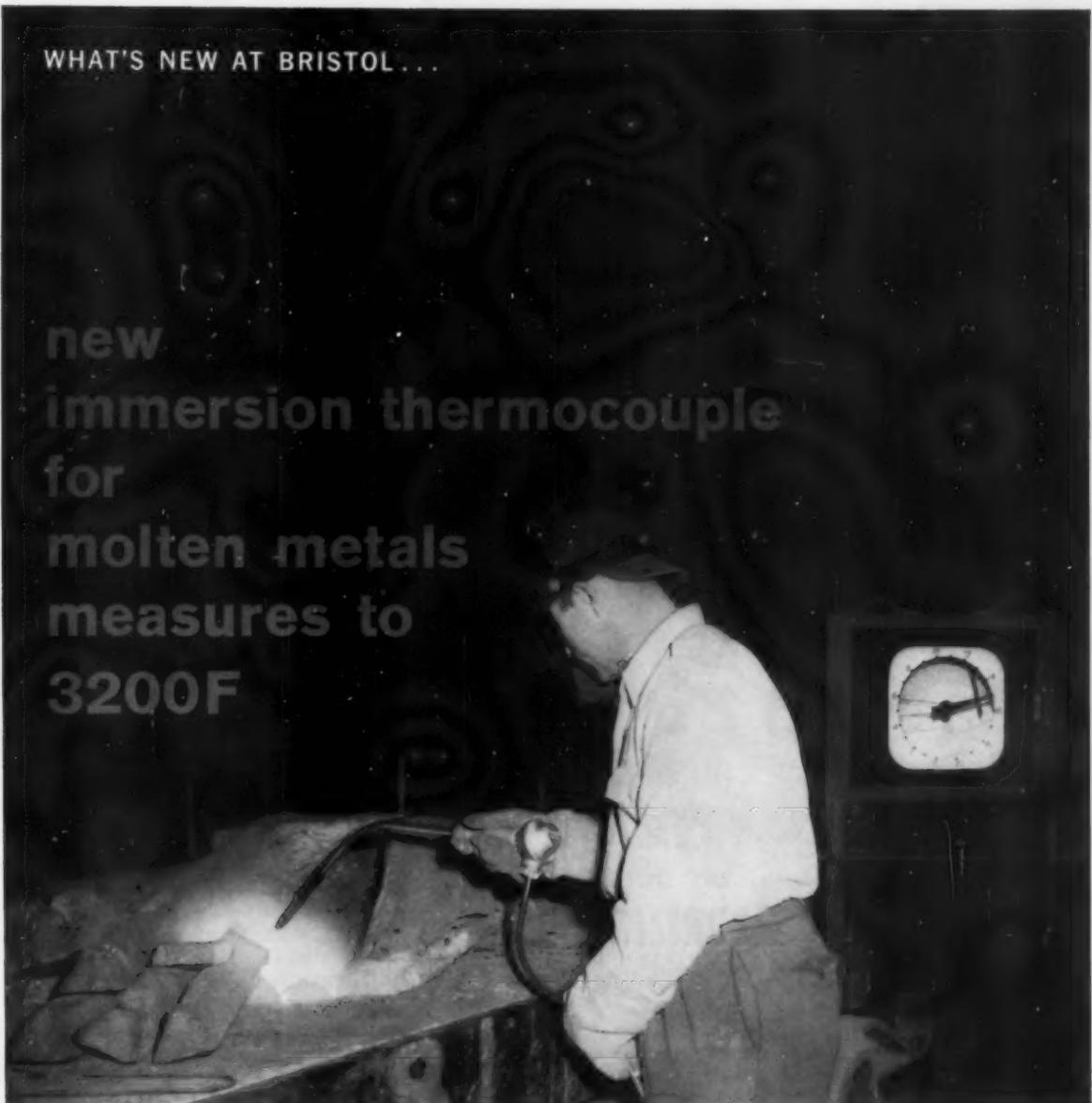
**T**WO BASIC TYPES of processes by which a steel part is given a hard, wear resistant surface overlying a ductile, shock resistant core are, first, those by which the chemical composition of surface layers is altered with respect to one or more elements, and second, those by which no surface chemical changes are brought about but the essential contrast in properties is achieved by preferential heating of the surface layers, followed by quenching. In the first group are included carburizing, carbo-nitriding, cyaniding and nitriding; in the second, induction and flame hardening.

Carburizing is the oldest of the processes and may be carried out by immersion of the part in a solid, liquid or gaseous carburizing medium. Today, gas carburizing holds a substantial edge, because of its inherent cleanliness, along with the economies it offers in fuel, labor and materials.

Requirements of a satisfactory gas carburizing atmosphere are three: low content of  $\text{CO}_2$  and  $\text{H}_2\text{O}$ ; a suitable proportion of  $\text{CH}_4$  or a higher hydrocarbon such as propane or butane which decomposes in the furnace to give methane; and the balance of the composition made up of  $\text{CO}_2$ ,  $\text{H}_2$  and  $\text{N}_2$ . Two methods are in use to generate these atmospheres. In the first, a neutral or mildly carburizing carrier gas prepared from city gas or other fuel gas in an atmosphere generator of

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immersion thermocouple  
for  
molten metals  
measures to  
3200F



**NEW BRISTOL IMMERSION THERMOCOUPLE** makes direct readings in melts of ferrous or non-ferrous metals, records on round-chart Bristol Dynamaster instrument (right).

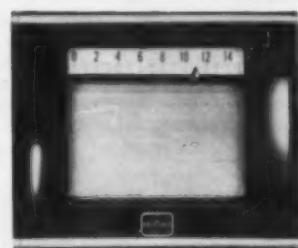
This new Bristol immersion-type thermocouple can take up to 14 dips in molten steel at 2700 F to 3200 F. With brass, aluminum and other metals of lower melting point, it has far longer life.

Simplicity, operating economy result from the new thermocouple's rugged, easily replaceable protection tubes. With reasonable care, they allow reuse of the expensive platinum sensing element.

This new Bristol immersion thermocouple is typical of recent outstanding Bristol developments in electronic pyrometry. Bristol's giant strides in automatic temperature control are making instrument systems obsolete which were designed new only a few years ago. Find out about these developments, before you buy any other instrument for furnace or oven. Write The Bristol Company, 106 Bristol Road, Waterbury 20, Conn. 7.23

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The furnace was originally used to carburize crank shafts and connecting rods. Uniform case depths were easily obtained, because conditions within the retort can be duplicated. Positive pressure prevents contaminating gases from entering the retort. Forced convection and multiple zone control assure rapid and uniform heat penetration in the densest of loads. Cooling of parts in a sealed pit prevents decarburization and scaling.

Stainless steel propeller shafts are clean hardened at higher temperatures without changing the equipment. The same gas is used in the retort, but parts are quenched in oil rather than air cooled.

This furnace may also be used for nitriding, carbonitriding, and clean or bright annealing. Write for Bulletin 646 to see how this furnace can provide you with years of trouble-free, versatile service.

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Heat Treating Furnaces... Electric Exclusively  
Dry Type Transformers Constant Current Regulators

## Case Hardening . . .

the endothermic type, and enriched with a small percentage of hydrocarbon, is fed to the furnace chamber. Typical endothermic gas composition is: 20 to 25% CO, 40 to 45% H<sub>2</sub>, 0.1% CO<sub>2</sub>, 1 to 2% CH<sub>4</sub>, and balance N<sub>2</sub>. Proportion of added butane may be up to 5%.

The second and less used method for atmosphere generation involves so-called liquid or drip feeds. Here an organic liquid, usually a mixture of isopropyl or methyl alcohol with benzene, is dripped directly into the furnace chamber, where it cracks to form an atmosphere of about 27% CO, 49% H<sub>2</sub>, 21% CH<sub>4</sub>, 0.4% CO<sub>2</sub> and the balance N<sub>2</sub>.

Control of surface carbon in the carburized case may be accomplished by introducing to the furnace an atmosphere of the required carbon potential throughout the cycle, or, more commonly, by the diffusion technique wherein the cycle is divided into two parts. In the first, carbon is supplied to the steel at the maximum rate at which it can be absorbed; and the second phase is diffusion in which the carbon potential of the atmosphere is reduced to the final level desired and the high-carbon surface allowed to diffuse until this level has been reached.

Modern gas carburizing furnace equipment is of many types: pit, horizontal, rotary, batch, or continuous tunnel systems — the latter often incorporating built-in quench chambers. Radiant tube heating is in widespread use in such furnaces.

Carbo-nitriding is another surface hardening process which has gained broad acceptance. Atmospheres may include any type suitable for gas carburizing, with the addition of a proportion of anhydrous ammonia to supply nitrogen to the case. The effect of atmosphere composition on carbon and nitrogen absorption is still not entirely clear, but in general the carbon absorption is related to the carbon potential, as in gas carburizing, while nitrogen absorption is related to the ammonia concentration, plus a certain temperature effect.

Metallography of carbo-nitrided cases is another aspect not yet fully investigated. From a practical standpoint the aim is to produce a



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## Case Hardening . . .

case which is fully martensitic after quenching, but it is difficult to avoid a little retained austenite. Thus, carbo-nitrided cases often display a slight falling off in hardness at the extreme surface. At higher temperatures, too high a nitrogen content results in precipitation of a black constituent at the grain boundaries, still not precisely identified.

Superficial hardness of induction and flame hardened cases depends primarily upon carbon content, which for the common specification of Rockwell C-60 should not be less than 0.40%, usually 0.45 to 0.50%. Specified carbon must be present right up to the surface and any decarburized skin must be removed by prior machining.

Advantageous features of induction and flame hardening include minimum scaling and distortion,

closer machining permissible before heat treatment, low specific consumption of energy, ease of localized hardening, high output rate, and adaptability to in-line production methods. ARTHUR H. ALLEN

## Homogenizing Treatment for Arsenic-Bearing Steel

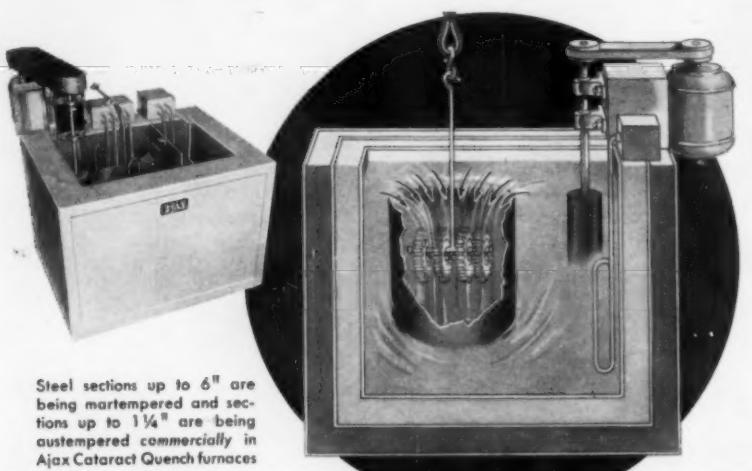
Digest of "The Diffusion of Arsenic in Steel", by D. S. Kazarnovskii, *Doklady Akademii Nauk S.S.R.*, Vol. 100, No. 6, 1955, p. 1073-1075.

ONE OF THE characteristic effects of the presence of arsenic in steel is the formation of a banded structure. This heterogeneous structure has been ascribed to microsegregation of the arsenic. In the regions high in arsenic the solubility of carbon in iron is lowered. It has been stated that this structure cannot be eliminated by heat treatment because arsenic does not diffuse in iron.

The present report discusses the diffusion of arsenic in high-carbon steel (0.87 to 0.80% C). Steel from five separate openhearth heats containing up to 0.313% As was used. The ingots were rolled into broad flange rails and specimens were cut from the rail webs. Specimens from each heat were (a) annealed at 1560° F. for 2 hr. and furnace cooled, (b) normalized from 1560° F. and cooled in air, (c) quenched from 1470° F. into water, (d) quenched from 1470° F. into water and tempered at 1110° F. for 1 hr., (e) homogenized at 2010° F. for 8 hr. and furnace cooled.

Annealing at 1470° F., normalizing, quenching, and quenching plus tempering increased the intensity of banding. The degree of banding, after various heat treatments, increased with the amount of arsenic in the steel. Four hours of homogenizing at 2010° F. decreased the degree of banding and 8 hr. at this temperature completely eliminated it.

No trace of banding was visible when samples which had been subjected to the homogenizing treatment were grain refined by quenching from 1470° F. in water. The author concludes that the properties of arsenical steels can be improved by this homogenizing treatment. Contrary to previous investigations arsenic has been shown to diffuse in austenite. W. A. MORGAN



Steel sections up to 6" are being martempered and sections up to 1 1/4" are being austempered commercially in Ajax Cataract Quench furnaces

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The quenching power of molten salt at 400° F. and above is tremendously increased by the rushing flow created in this unique Ajax "Cataract" furnace design. As a result, any steel that can be hardened satisfactorily by an oil quench can now be martempered or austempered in salt—with all of the salt bath advantages.

These include more uniform hardness; so little distortion that parts can usually be finish machined before hardening; elimination of quench cracks; and increased toughness and ductility. Also, like all salt baths, Ajax Cataract Quench Furnaces are readily mechanized.

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WRITE for Ajax Martempering and Austempering case history bulletins.

*Tear this chart out and preserve it*

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| TYPE AND GRADES                        | DESCRIPTION   | HARDENING RANGE      | QUENCH          | TEMPERING RANGE    | USEFUL HARDNESS |
|--|---|----------------------|-----------------|--------------------|-----------------|
| W1 Grade 1<br>Columbia SPECIAL         | Best quality water hardening tool steel — meets all metallurgical tests   | 1420° F. to 1530° F. | Water and Brine | 350° F. to 500° F. | 67/59 Rc        |
| W2 Grade 2<br>VANADIUM EXTRA           | Vanadium treated modification of Columbia EXTRA, fine grained, tough, long wearing carbon tool steel  | 1425° F. to 1500° F. | Water and Brine | 350° F. to 500° F. | 64/58 Rc        |
| W5 Grade 2<br>WATERDIE EXTRA           | Chromium alloyed Columbia EXTRA for increasing depth of hardness and wear properties  | 1475° F. to 1525° F. | Water and Brine | 350° F. to 500° F. | 65/56 Rc        |
| W1 Grade 2<br>Columbia EXTRA           | Extra quality straight carbon tool steel — meets hot-etch and hardenability tests, wide range of uses   | 1420° F. to 1550° F. | Water and Brine | 350° F. to 550° F. | 65/57 Rc        |
| W1 Grade 2 Columbia<br>EXTRA HEADERDIE | Selected carbon with controlled hardenability to meet severe physical requirements of cold heading<br>Metallurgically controlled for center soundness | 1470° F. to 1550° F. | Water and Brine | 400° F. to 530° F. | 63/58 Rc        |
| W2 Grade 3<br>VANADIUM<br>STANDARD     | Vanadium treated Columbia STANDARD — a shallow hardening fine grained tool steel for general purposes   | 1420° F. to 1470° F. | Water and Brine | 400° F. to 550° F. | 63/56 Rc        |
| W1 Grade 3<br>Columbia STANDARD        | A good quality reliable straight carbon, general purpose tool steel for short run tools not requiring the high physical properties                    | 1420° F. to 1470° F. | Water and Brine | 400° F. to 550° F. | 63/56 Rc        |

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## The Nature and Geometry of Dislocations

Digest of "Dislocations and Plastic Properties of Metals", by J. Philibert, *Metaux-Corrosion-Industries*, No. 368, April 1956, p. 154-166.

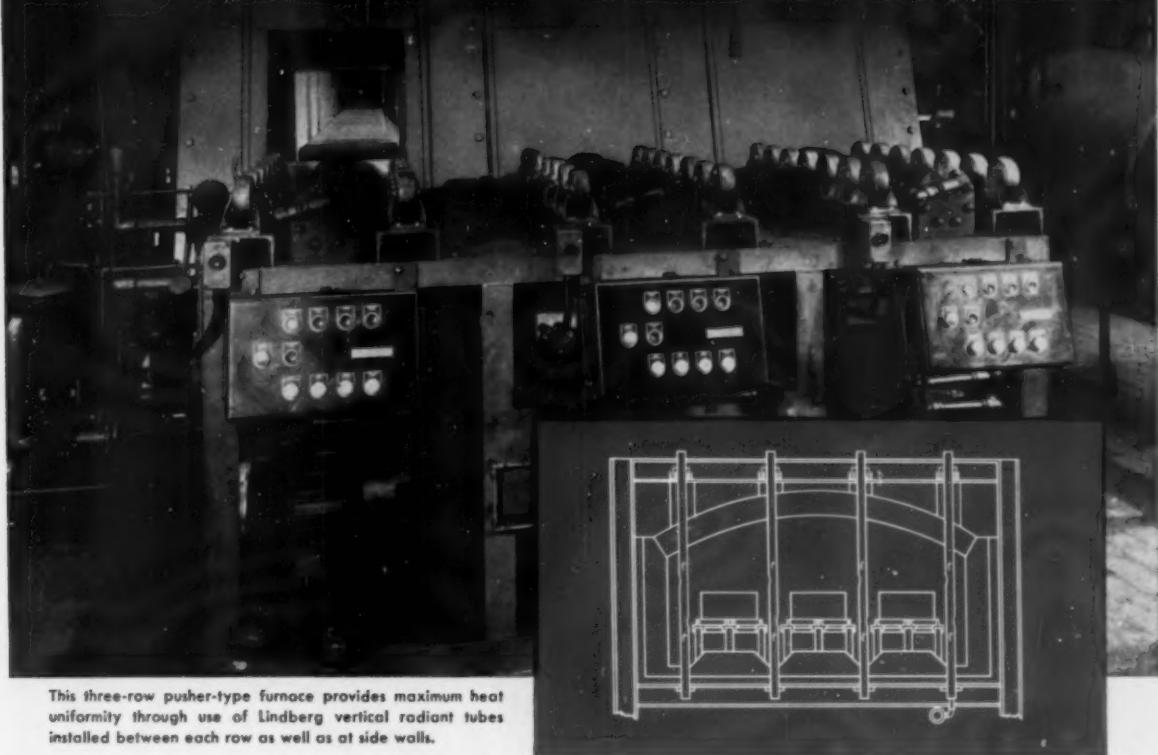
**I**N THE INTRODUCTION the author relates briefly the origin of the concept of dislocations and its evolution up to the present time. Indeed, the rather recent improvements in metallurgical techniques have made it possible to examine "real" dislocations in nonmetallic and metallic crystals. Several experimental laws governing the plastic properties of crystalline solids can now be explained by the theory of dislocations. Some of the most direct proofs of their existence and the usefulness of their application are given by the author with particular reference to the plastic properties of metals.

The author has studied in some detail the nature and geometry of dislocations — for example, sub-boundaries, piled-up groups and their effect on brittle fractures, and the interaction of dislocations with solute atoms or impurities during strain aging.

The scientists have rejected the idea of the perfect crystal because of the large discrepancy between the theoretical and experimental values of the yield point. For instance, in a single crystal the critical shearing stress necessary to produce an elastic deformation may be 100 times as low as the theoretical value. The concept of the edge dislocation is introduced into the picture and it is shown that there would be no disagreement between the theoretical and experimental values in a perfect crystal (free from dislocations) but that the size of the latter would then have to be of the order of the mosaic structure of the crystal — that is, a few microns such as the so-called metal whiskers.

In brittle fracture a similar disagreement exists between the calculated decohesive strength of a crystal along a given cleavage plane and the experimental rupture strength. The theory of Griffith does not give a satisfactory explanation for the discrepancy for metals, and it is

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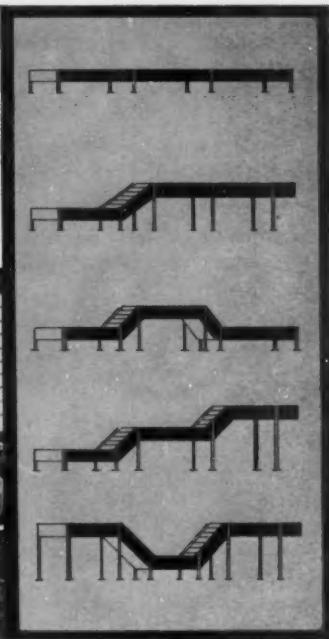
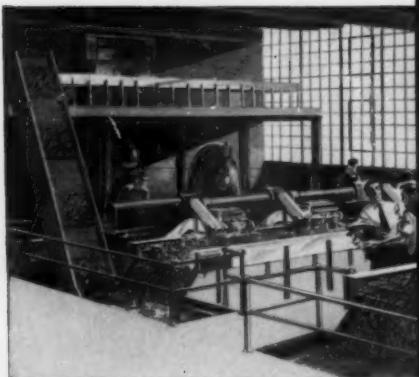
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## **Dislocations . . .**

found that certain configurations of dislocations, namely the piled-up groups, favorably substitute for the Griffith cracks and give the solution sought for. The theory of dislocations may also be used satisfactorily to predict the influence of grain size on the brittle fracture of metals and the ductile-brittle transition. The author shows electron micrographs of a fractured low-carbon steel representing steps and "rivers" probably formed by the cleavage surface when the screw dislocations are cut perpendicular to the surface.

If the displacement of individual dislocations cannot readily be observed, it is possible to follow the movement of stable "walls" of dislocations or sub-boundaries. It is shown that such a movement is a function of the movement of each dislocation of the sub-boundaries as in zinc bicrystals and that the temperature has a marked influence on the processes. Apart from their motion along a slip plane the dislocations may also climb or diffuse out of their slip plane as explained by the Frenchmen J. Friedel, C. Boulanger and C. Crussard in their work on polygonized aluminum (*Acta Metallurgica*, No. 3, 1955, p. 380). Here again, the theory agrees particularly well with some experimental findings in the interpretation of the anomalous behavior of polygonized aluminum tested at high and low temperatures.

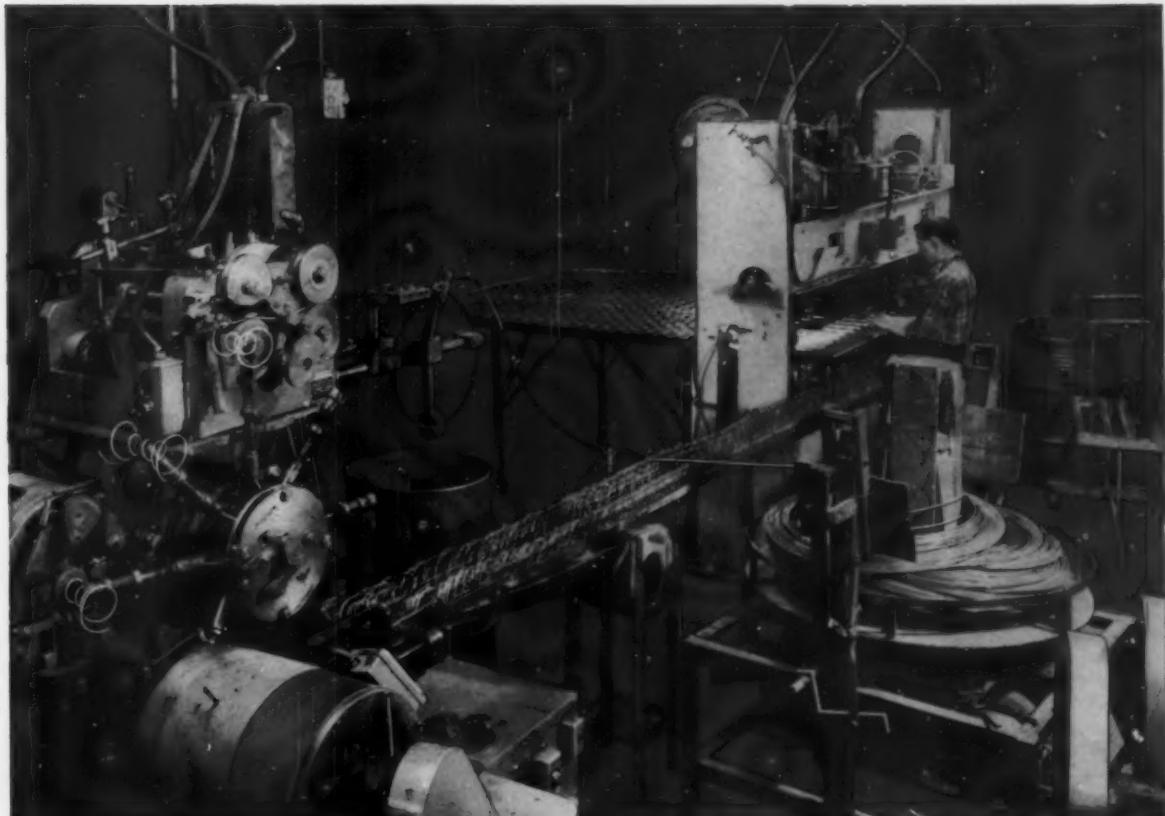
The difference between quench and strain aging is emphasized and the author demonstrates the usefulness of the theory of dislocations for studying the kinetics of strain aging, the manifestation of which can be accounted for by the interaction of dislocations with the segregated impurities. From theoretical considerations and experimental results the density of dislocations, the heat of activation of the processes and the density of the clouds of segregated impurities or solute atoms can be tabulated.

Many other experimental laws are solely governed by the theory of dislocations, such as polygonization during creep, but two of the most significant examples in favor of the theory remain the kinetics of strain aging and the movement of sub-boundaries.

PIERRE CHOLLET



Double cone springs are produced automatically on this Wunderlich special high speed automatic coiling and knotting machine at the Sealy Mattress Company, Cleveland, Ohio. Machine coils, crimps, knots and heat treats springs made from 13½ gage Mastercraft spring wire, supplied in 600 lb. bundles.



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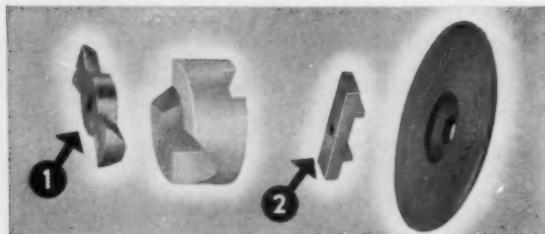
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# MEETING DESIGN NEEDS

## BRASS POWDER FORMS IMPORTANT CONNECTION FOR WESTERN ELECTRIC

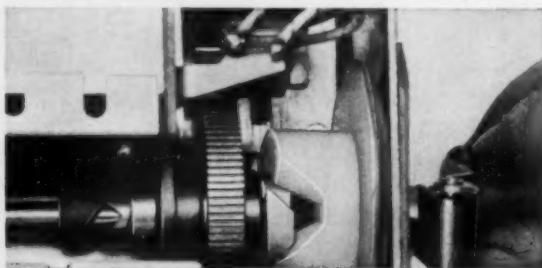


The Clutch Coupling (1) and Bar Coupling (2), shown above, function with two insulators to form an important drive linkage in Western Electric's "lineman's test set". These BRASS POWDER parts perform the dual role of activating a signaling generator and retaining a molded nylon cam that insulates the handle up to 10,000 volts.

The complex, curved surfaces on the blades of the Clutch Coupling would be very difficult and expensive to machine from bar stock. For this reason, Western Electric designed both of these parts for the powder metal process and turned the job over to an experienced fabricator\*. Thus, unit cost was very low, high performance standards were met and much valuable machining time was saved.

Consult with a metal powder fabricator when you have difficult design problems—or when you simply want to lower your production costs with BRASS POWDER sinterings.

\*Parker White-Metal Company, Erie, Pa.



Detail of the Clutch Assembly on Western Electric's signaling generator. The Bar Coupling turns the Nylon Cam which pushes the Clutch Coupling forward to engage the drive gear.

### How Can BRASS AND NICKEL SILVER POWDER PARTS Meet Your Design Needs?



For detailed information on the design, properties, production and application of brass and other nonferrous powder parts you should have a copy of our manual. It will give you 20 case histories of brass and nickel silver powder structural parts to assist in evaluating this means of production in terms of your particular needs.

◀ SEND FOR YOUR COPY



### Oxygen Cutting Causes Cracks in Cast Armor Plate

Digest of "Transverse Cracking Resulting from Oxygen Cutting", by Norman N. Breyer, *Welding Journal*, Vol. 35, September 1956, p. 865-876.

IN EARLY STAGES of manufacture of the M-48 medium tank, radiographic examination disclosed cracks in the austenitic welded joints between the cast armor plate hull and rolled armor plate floor section. About 200 in. of weld is required to join the floor plate to the hull casting, with a double-vee full penetration joint specified.

Hulls were of two types of armor steel: one made in the basic open-hearth furnace and containing about 2.50% Cr and 0.50% Mo, with 0.50 to 0.80% Mn; the other melted in the acid openhearth furnace and containing around 1% Cr, 1% Ni, 0.50% Mo and 0.80 to 1.30% Mn. Most were of one-piece design, although a portion comprised welded assemblies of four main castings each.

Normal procedure for preparing the casting side of the weld joint made use of an oxygen cutting fixture in which the excess stock was removed in two cuts providing a double beveled edge for the weld. Rate of travel of the oxygen cutting tip was 7 to 8 in. per min.

Transverse radiographic discontinuities on the casting side of the floor plate joint were discovered to varying degree in all hulls examined. The minute transverse cracks, not visible to the eye, appeared after the oxygen cutting operation. They were found only on the surface beveled by the first cutting torch, and were clearly delineated by dye checking. The number of cracks per hull varied from as few as a dozen to more than 400.

As proof of the time of crack incidence, certain hulls were allowed to cool to room temperature after the first bevel cut and they showed no transverse cracks upon dye checking. However, checking this first surface cut again after the second bevel cut disclosed the presence of the cracks. An interesting point was that the cracks did not start at the apex of the double bevel, but

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Shown is one of the largest nitriding furnace installations in the country furnished by Drever Company and located at National Forge and Ordnance Company, Warren County, Pennsylvania, used for nitriding large diesel engine crankshafts.

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- Two (2) 150-KW Furnace Bells
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The work chamber is 7'-4" diameter x 13'-6" high, equipped with an alloy inner pedestal for supporting work vertically. Furnace is capable of handling a 21,000 pound charge for nitriding at 1050° F for a normal cycle of 72 hours.



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## Oxygen Cutting . . .

were about  $\frac{1}{8}$  in. back from it. The average depth of the cracks was 0.068 in.

The original expedient to correct the condition was to remove the cracked area by grinding, then to fill in the void with stainless steel welding electrode and finally grind the surface smooth. This was a costly procedure and did not solve

the basic problem. It was also thought that the cracks might possibly weld out when the austenitic electrode metal was applied to the oxygen-cut edge when welding the floor plate in place. Radiographic examination of completed welds showed the cracks still in existence.

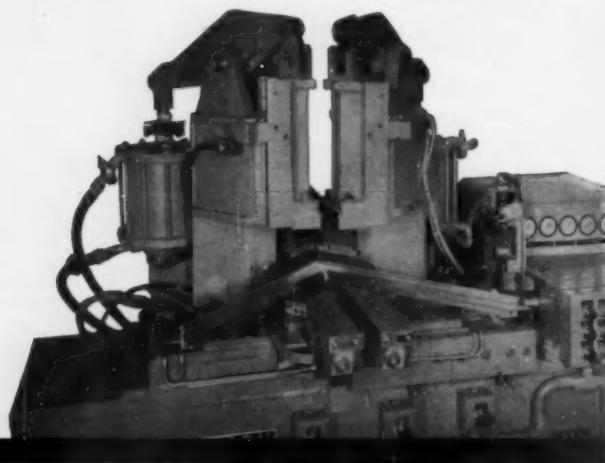
In approaching a final solution to the problem, two objectives were kept in mind: first to attempt to reduce the tensile stress condition on the first cut edge introduced by

the second cutting operation, and second, to improve ductility properties of the first cut edge so that it would be in a more favorable state to accommodate the stress condition. It was reasoned that the application of preheat would accomplish both objectives.

Four methods of preheating were tried with only partial success. They included utilization of a "scrap" cut to create heat input before subsequent beveling; the use of a lead preheat torch on the first oxygen cut surface during the second bevel-cutting operation; a postheat operation following the first cut; and reduction of oxygen cutting pressure.

A fifth and most successful procedure was to set up a ring-type gas burner around the entire edge of the hull opening which played a series of small flames continuously against the scarfing stock. Using natural gas of 1024 Btu. content, the hull was readily preheated to 350° F. prior to the beveling operation. Transverse cracking was thereby reduced to an insignificant level and about 6 hr. of crack removal time and repair welding were eliminated.

ARTHUR H. ALLEN



*Darwin*

### PRK • 33 TOOL STEEL

(Cobalt, High Carbon, High Chrome)

\*Holds its edge at 1000° F.!

- Above is the Thomson Synchro-Matic Flash Welder performing a miter weld on an aluminum window extrusion. "Pinch-off" dies of PRK-33, a Thomson development, support the work close to the point of weld. After welding, this PRK-33 die moves in to pinch off the flash close to the surface of the work. Eliminates most cleaning and finishing of the weld.
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## Printed Electrical Circuits

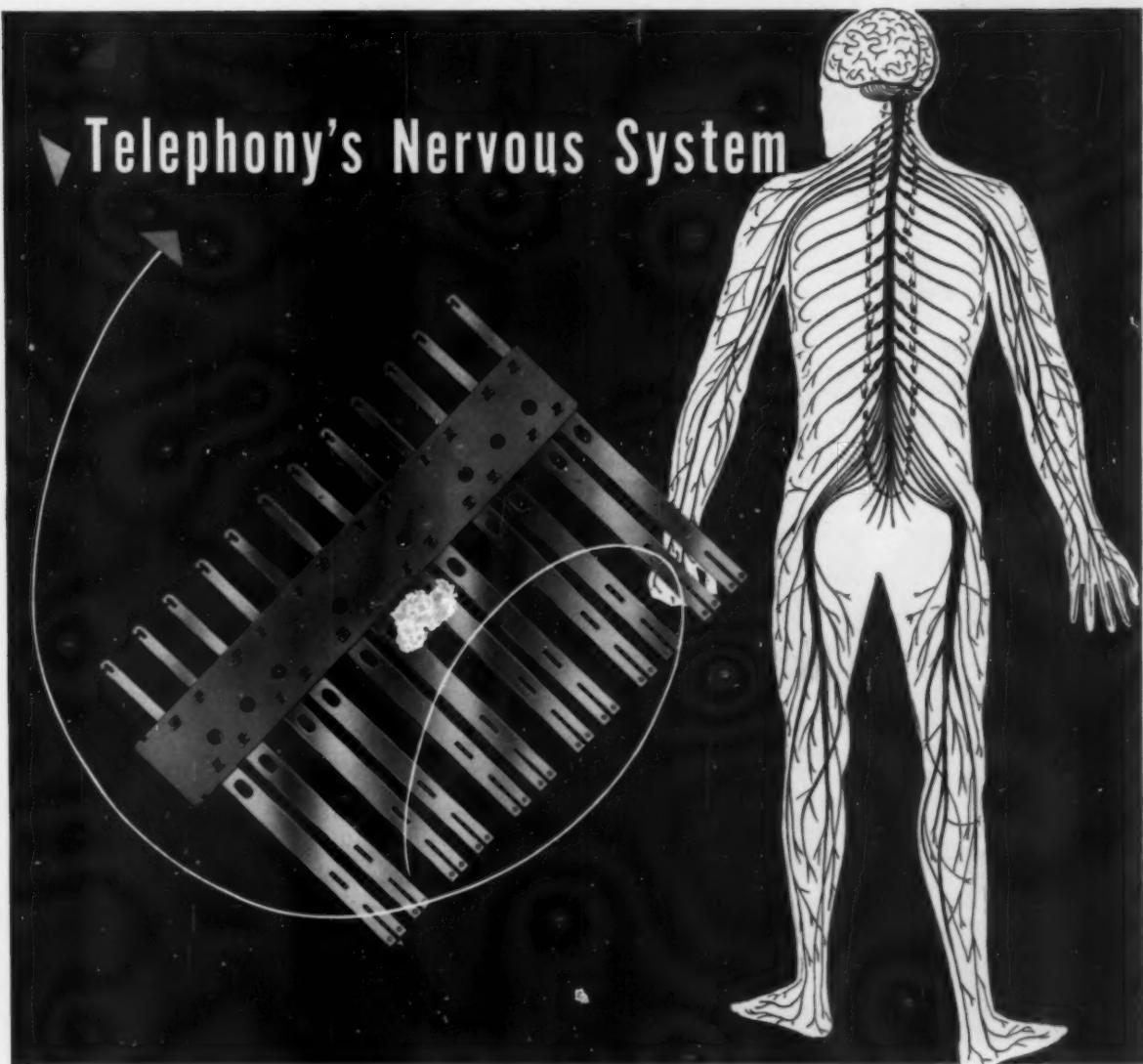
Digest of "A World of Electricity in Miniature—the Printed Circuit", *Bakelite Review*, January 1957, p. 3-6.

THE complex field of electronics poses economic and quality control problems associated with hand-wiring operations in manufacturing. The printed circuit is one answer to this immediate need for electronic circuit miniaturization and economy. It is also an important step in the direction of automation.

A printed circuit is a thin, reproducible, electrical path bonded in a predetermined pattern to a nonconductive base. Various electronic and electrical components are placed on this base and all connections to the printed path are made at one time by a process of dip soldering. Conventional wiring is eliminated as well as tedious hand labor. By this process, thousands of units can be reproduced accurately with consistent electrical properties.

Success of the printed circuit was based on the development of insul-

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## Printed Circuits . . .

ating materials with a proper balance of electrical and mechanical properties. Bakelite phenolic resins have proved to be very successful in this application.

A printed circuit begins with an insulating base of paper impregnated with resin. A sandwich of impregnated paper sheets is laminated in hydraulic presses at high temperature and pressure. The next step in the process is to bond copper foil to the paper base. One commonly used process for this incorporates a

top layer of adhesive and foil in the laminate. The pressing operation permanently bonds the foil to the baseboard.

In actual production there are more than 25 popular methods of applying a conductive pattern to a base. One of the most used methods involves the printing of a circuit in acid resistant ink on the metallic foil bonded to the base. Dipping the board in acid dissolves or etches the unprotected foil. The ink is then washed away and the printed circuit is left in conducting foil. After any necessary machining is performed, the electronic components are

mounted on the base. To make the electrical connections, the leads of the components must be soldered to specific points along the printed path. This is done by dipping the entire assembly into hot solder. All the connections are made at one time and the costly hand soldering operations are eliminated.

The entire process—the production of the base and the printing of the circuit—permits rapid, economical, and uniform production of electronic assemblies.

GLENN P. LAEL, JR.

## Evaluation of Brittle Fracture Tests

Digest of "Evaluation of a Method of Determining the Tendency of Mild Steel to Brittle Fracture", Centrum Voor Lasttechniek N.V.L. — T.N.O., Report No. SR532/1A, April 1955, 99 p.

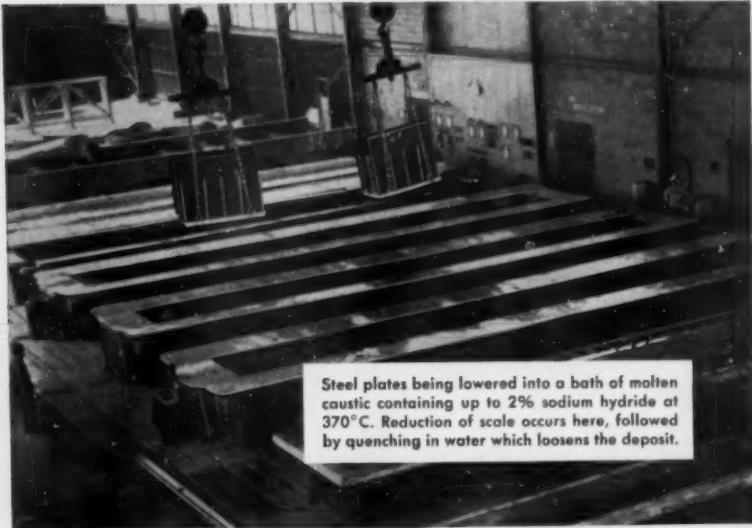
THIS REPORT is the result of cooperative research in the Netherlands and Belgium on the problem of brittle fracture. The object was to evaluate the numerous tests now available to assess the susceptibility of a steel to brittle fracture and to arrive at a single test to be used universally. The investigation demonstrated that various tests show hardly any essential differences.

Tests were carried out on plates greater in thickness than  $\frac{1}{8}$  in. and on three types of steel: (a) an open-hearth killed steel, normalized after rolling, (b) a Thomas process rimmed steel, not heat treated after rolling, (c) a commercial grade of steel of unknown origin and unknown method of manufacture.

On these steels impact tests of the following types were made: (a) I.S.A., (b) Schnadt, (c) Charpy-Izod. Further impact tests were made in which the temperature was kept constant and the notch radius varied. These latter tests were of the I.S.A. and Schnadt types.

Static (slow bend) tests were also made on unwelded steel, employing the Soete test (4-point bend tests on specimens notched on three sides), and the Van der Veen test; and on steel subjected to a welding operation using the Kommerell test and the slow bend test on sharp-notched specimens with the base of

(Continued on p. 158)



Courtesy Lukens Steel Co.

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The sodium hydride process for descaling stainless and alloy steels saves time, money and metal. It is much faster than pickling—15 seconds to 20 minutes instead of several hours. The process reacts with scale only, and does not attack the base metal. Pitting is eliminated and original dimensional accuracy is maintained.

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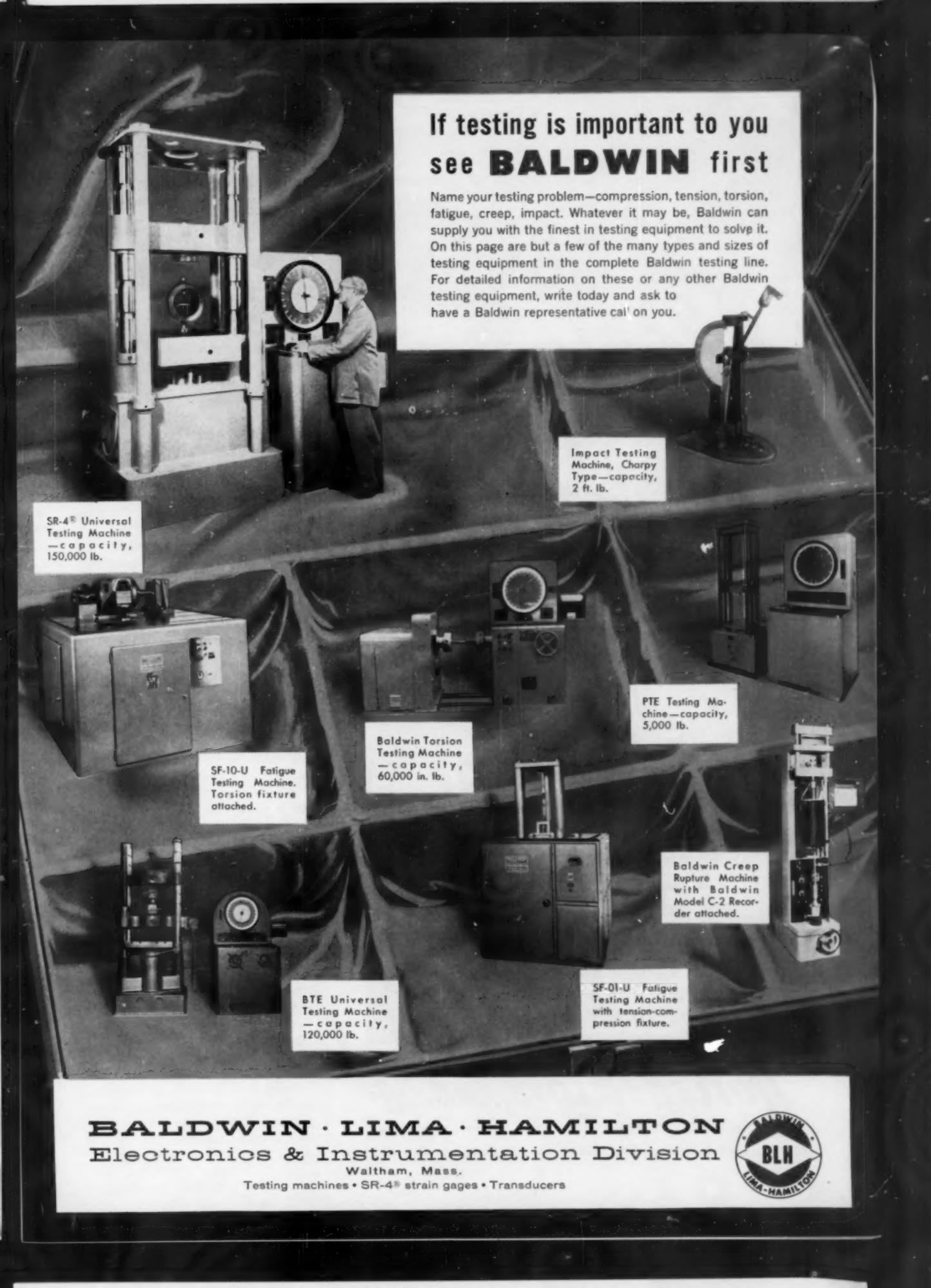
"About five years ago we furnished a replacement 8 ft. x 15 ft. dryer drum to a customer whose dryer had been in service on a Simplicity Asphalt Plant for 25 years. The steel tires and bull gear of the old dryer showed no signs of wear and were used in the new drum. Those rings were supplied to us by Standard Steel Works. That's why we know the quality of Standard's rings is as good as the service they render us," says Harlan Whitfield, of The Simplicity System Company, Chattanooga, Tenn.

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## Brittle Fracture . . .

the notch in the fusion zone of a weld bead.

The Van der Veen notched slow bend test uses a specimen with dimensions  $70 \times 225 \times t$  mm. ( $t$  = plate thickness). The notch is 3 mm. deep, included angle 45°, root radius as small as possible. The notch is made with a hardened steel knife which is pressed into the steel to the required depth within a half hour of testing. Specimens are tested as beams freely supported on two rollers with a point load in the

middle. The span is usually 200 mm. at 50 mm. roller diameter and 60 mm. mandrel diameter. The notch is in the tension face of the specimen, exactly opposite the point of contact with the mandrel.

From the large number of tests made on various types of impact and notch-bend specimens at different temperatures certain test requirements were established. Requirements determining the tendency of a steel to brittle failure are:

1. The test should allow separate determinations of fracture appearance transition temperature and ductility transition temperature.

2. It must reflect the influence of plate thickness on transition temperature.

3. The initial load should not be an impact load.

Criteria for measuring the tendency toward brittle fracture are the ductility transition temperature for the behavior of a complete structure, or the fracture appearance transition temperature. The former cannot be determined by a laboratory test because of its dependence on geometry or design, which cannot be imitated in a test. The fracture appearance transition temperature can be found experimentally. It is a measure of the resistance of the steel to propagation of an initial crack in a brittle fashion.

The advantages of slow bend tests on notched specimens over notched-bar impact tests are:

1. The initial load is static.
2. The specimens are large enough to minimize edge effects.
3. Ductility transition temperature and fracture appearance transition temperature can be determined separately.

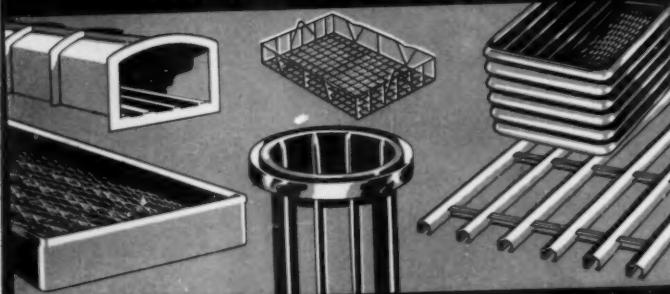
Of the slow bend tests the Van der Veen test is preferable because, (a) the two transition temperatures can be determined separately, (b) the severity of the pressed-in notch approximates that of a natural crack, (c) the full plate thickness is tested, (d) the fracture propagates parallel to the plate surface, (e) specimens can be made simply and rapidly, (f) test equipment is simple and testing is rapid and accurate.

Of the impact test types the V-notch Charpy is preferred by the reviewer, based on practical factors rather than theoretical considerations. This type was used in investigating material from fractured Liberty ships and is still widely used in the United States and Britain. Furthermore this test is recommended by the International Institute of Welding as an international standard. As a consequence, much more reference data are available for this type of test than for any other. For these reasons the Dutch Commission supports the effort of the I.I.W. to standardize on this test.

The results obtained with the Schnadt type tests do not encourage its use for routine testing. The preparation of the specimens, moreover, is time consuming.

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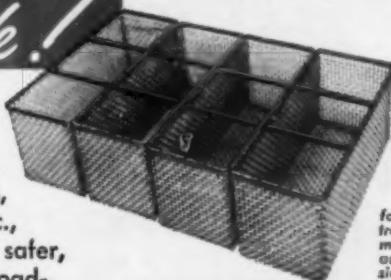
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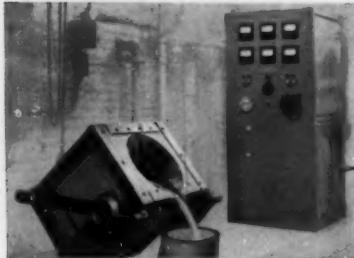
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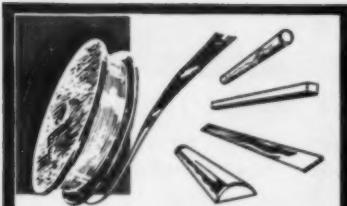
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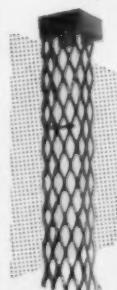
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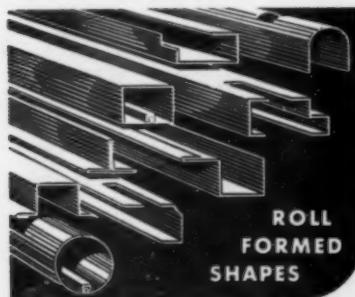
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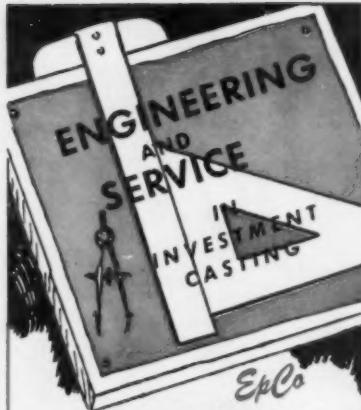
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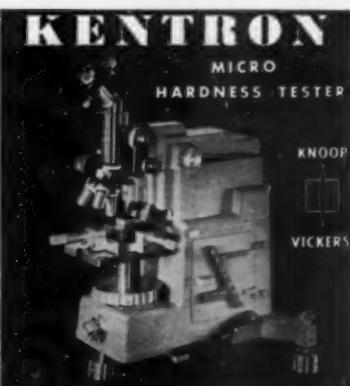
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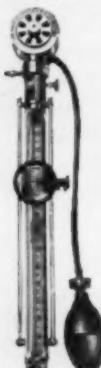
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## Hydrogen in Weld Metal

Digest of "Hydrogen — Barrier to Welding Progress", By C. L. M. Cottrell, *British Welding Journal* Vol. 1, April 1954, p. 167-176.

THE PRESENCE of hydrogen during fusion welding of steel can lead to cracks in both the weld deposit and the heat-affected zone of the welded plate. In arc welding, most of the hydrogen comes from the electrode coating and much of it is dissolved by the molten steel, in which it is soluble to the extent of 30 ml. per 100 g. at 2910° F. On solidification the solubility drops to 13 ml. per 100 g., and on cooling further it falls gradually, except for a sudden drop at the gamma-alpha transformation, to practically zero below 600° F. Atomic hydrogen can diffuse through steel at room temperature, the rate increasing at higher temperatures though it is lower in austenite.

With a weld high in hydrogen, cooling is too rapid for much hydrogen to be lost by diffusion until the transformation temperature is passed. Then, as the solubility drops, diffusion increases, and cooling is slower, so that at 950° F. the internal hydrogen pressure rises and the hydrogen content falls. When a weld containing 30 ml. hydrogen per 100 g. when molten, cools from 1650 to 212° F. in 20 sec., the hydrogen reaches a maximum pressure of 47,000 psi., and only one sixth of it diffuses out; when this cooling takes 120 sec., the maximum pressure reaches only 31,400 psi., but nearly all the hydrogen is diffused. A weld containing only 10 ml. hydrogen per 100 g. when molten, cooling in 20 sec. from 1650 to 212° F., develops a maximum pressure of 6700 psi.

Austenitic welds, having no transformation, lose very little hydrogen on cooling, and may contain as much as 32 ml. hydrogen per 100 g. at room temperature. The base plate adjacent to such welds thus absorbs very little hydrogen from them. Ferritic electrodes having cellulosic, rutile, rutile-basic, or oxide-silicate coatings produce welds having high diffusible hydrogen contents (19 to 27 ml. per 100 g.) and hence can add considerable hydrogen to the adjacent plate. Oxidizing and low-hydrogen coat-



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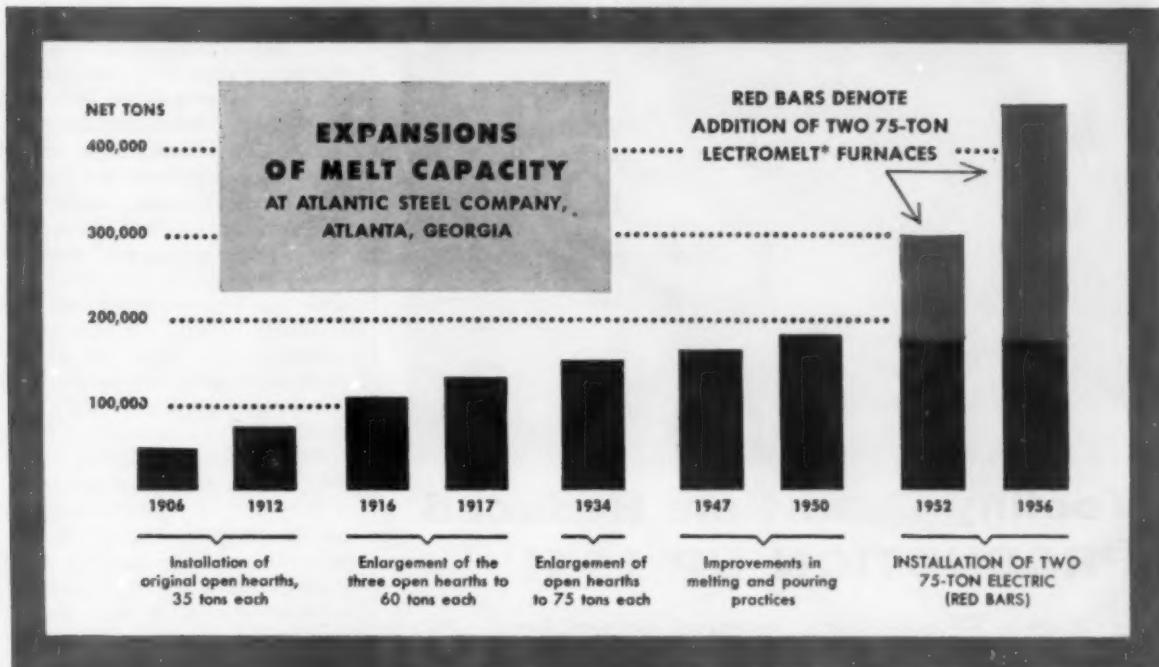
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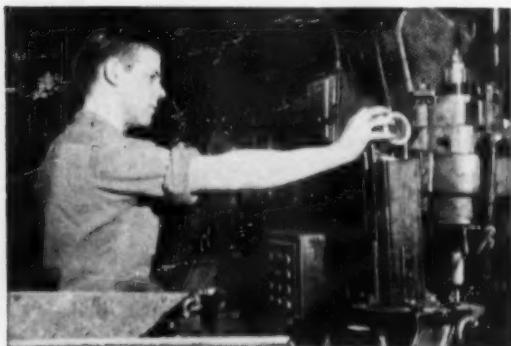


Photo at top shows General Foreman Robert Welch giving "specification plus" okay to DBM fittings as Vulcan representative examines tap used in manufacture.

Photo at left shows typical tapping machine operation at Detroit Brass & Malleable Company's nine-acre site.

**HKP** VULCAN CRUCIBLE STEEL DIVISION  
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## Hydrogen in Welds . . .

ings give off very little hydrogen (3 ml. or less per 100 g.), in either weld or plate.

Cold cracking of the heat-affected zone in welded high-tensile steels varies with the alloy content of the steel, the restraint of the joint in welding, and cooling rate of the weld, as well as with the hydrogen absorbed by diffusion from the weld deposit. Cold cracks were found in the heat-affected zone of a welded manganese-molybdenum steel, irrespective of the degree of restraint, only when the cooling rate exceeded 11° F. per sec. at 570° F. This critical cooling rate varied with the diffusible hydrogen in the weld deposit, from 90° F. per sec. with 1 ml. hydrogen per 100 g. to about 7° F. per sec. with 25 ml. hydrogen per 100 g.

The effect of 14 ml. hydrogen per 100 g. on the mechanical properties of three low-alloy structural steels was investigated, using hollow cylindrical specimens rapidly heat treated in an induction furnace to simulate welding thermal cycles. The notched impact resistance rose consistently with faster cooling, either with or without hydrogen. Hydrogen decreased the impact strength of a 0.19% C, manganese-molybdenum steel, but not that of a 0.11% C, boron-molybdenum steel. In tensile tests of unnotched specimens, hydrogen decreased both strength and ductility of the manganese-molybdenum steel, but only the ductility of the more ductile boron-molybdenum steel.

The minimum dead-load tensile stress required to produce rupture of notched specimens, with and without hydrogen, in less than 150 hr., gives a direct indication of the liability of the heat-affected zone to crack in welding. The 0.11% C, boron-molybdenum steel containing hydrogen showed high strength (over 110,000 psi.) regardless of cooling rate, and did not crack when welded. Manganese steels with 0.19% or more carbon and containing hydrogen showed weakness in this test (less than 110,000 psi.) when cooled in less than 25 sec. from 1600 to 570° F.

A low carbon content is important for good resistance to weld cracking. Carbon segregation may greatly de-

crease the advantage gained from using low-hydrogen electrodes. With austenitic electrodes the critical end-of-transformation temperature may be lower than 400° F., permitting crack-free welding of higher carbon steels without preheat, but the hydrogen in the austenitic deposit might diffuse dangerously if the welded joint were heat treated.

The author concludes that freedom from cracking can be attained by holding any *one* of the four factors — hydrogen content, cooling rate, alloy content, internal stress — at a very low value, or all of them at a fairly low value. The bad effects of hydrogen in welding can be avoided by (a) using steels of maximum weldability (low carbon), (b) using extra-low-hydrogen electrodes, (c) controlling the cooling rate through preheat or weld size, and (d) welding with dry electrodes, using normal care with dry steel not too cold. G. F. COMSTOCK

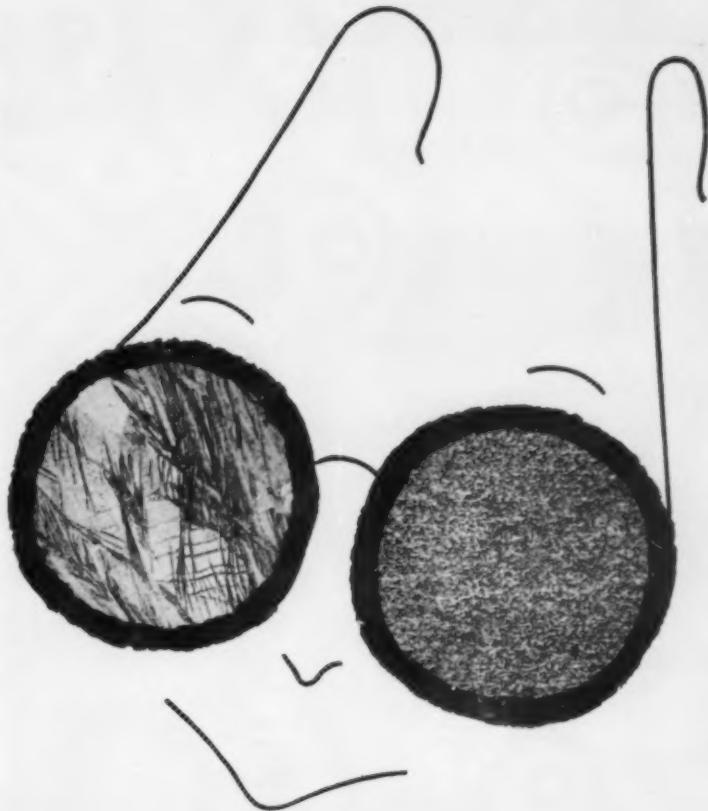
## Pearlite Reaction in Alloy Steel

Digest of "The Pearlite Reaction in Alloy Steel", by R. I. Entin, *Metallovedenie i Obrabotka Metallov*, No. 9, 1956, p. 3-9; No. 10, 1956, p. 20-28.

A STRANGE ASPECT of the Russian technical literature is the article that mercilessly attacks and systematically demolishes the facts or theories of a previous work. The present long, two-part article by Entin is such a criticism of a paper with the same title by M. E. Blanter, a digest of which appeared in *Metal Progress*, November 1956, p. 180.

One of Blanter's basic ideas is that cementite,  $(Fe,Me)_3C$ , having the same content of the alloying element (Me) as the steel as a whole, is the initial carbide in pearlite, even though a complex carbide or cementite enriched in the alloying element may be the equilibrium phase. Entin thoroughly discredits this idea by presenting tabulations of experimental results from Russian and "foreign" literature establishing the following facts:

1. In the initial stage of the transformation of austenite to pearlite in many steels containing alloying elements such as chromium, molybdenum, tungsten, or vanadium, the



## You can see the difference

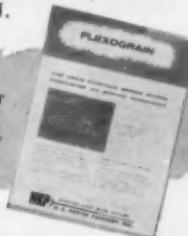
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### Pearlite Reaction . . .

first carbide that forms is a special carbide, and not cementite.

2. These carbides are greatly enriched in the alloying element.

3. However, when the austenite transforms at lower temperatures (in the bainite range), the initial carbide is cementite and it contains the average alloy content.

Thus, Entin shows that Blanter misinterpreted data that actually described a bainite reaction (rather than a pearlite reaction) and that Blanter failed to consider other data that were readily available.

Two other points in Blanter's theory are also attacked. His claim that shifts in the  $A_1$  temperature are important is refuted by reference to the literature, and a counter proposal is made that the true effect is the influence of alloying elements on the kinetics of the allotropic transformation of iron. Also, Blanter had used the idea of coherency at the austenite-pearlite interface. Entin attempts to show that coherency is not important in the pearlite range but only in transformations that involve substantial undercooling of the decomposing phase — namely, austenite, in this instance. A. G. Guy

### New Al, Mg, Ti Alloys for Aircraft and Missiles

Digest of "Performance of Light Metals at Elevated Temperatures", by Alan V. Levy, *Light Metal Age*, Vol. 14, December 1956, p. 12-15.

AIRCRAFT and missile structures, subject to aerodynamic heating, require concentrated attention to properties of the materials and to operating conditions. Pertinent factors include loads and their methods of application, sources and distribution of heat, service time at temperature, variations in strength and modulus of elasticity with temperature, oxidation and thermal expansion characteristics, thermal conductivity, surface emissivity and metallurgical stability at temperature.

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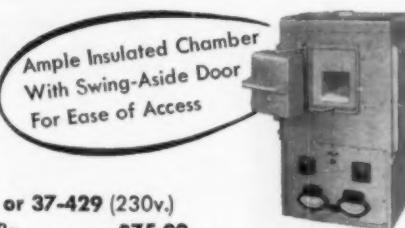
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**Aircraft Alloys . . .**

be more extended creep properties must be given careful consideration.

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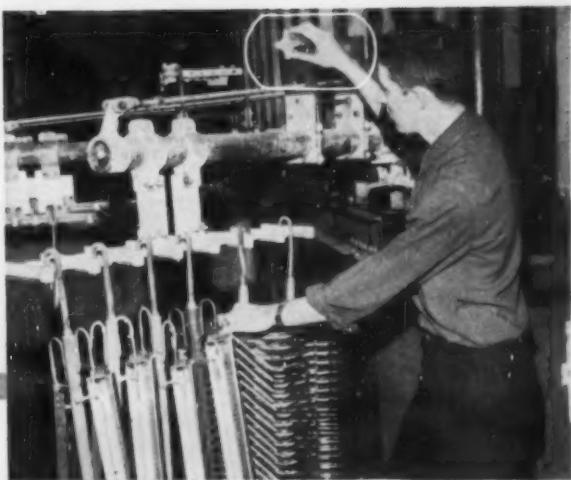
The most promising standard wrought alloys of aluminum suitable for elevated-temperature installations are those containing appreciable amounts of copper, such as the 2014 and 2024 analyses, the latter being serviceable up to about 600° F.

Recent additions to the aluminum family of alloys for elevated-temperature use include the wrought alloy X 2219, containing nickel, and the cast alloy XA 140, a high-copper, high-magnesium material. However, the newest concept in aluminum structural alloys appears to be based on powder metallurgy — a Swiss development. It is a sintered and worked material made from part aluminum powder and part aluminum oxide. Although no method for welding powder metal alloys has been developed to date, they can be satisfactorily formed, machined and mechanically fastened.

Several new wrought and cast magnesium alloys have appeared on the aircraft scene, with properties actually exceeding those of the best aluminum alloys at the high end of the service temperature range up to 800° F. One is a thorium-zirconium alloy, HK 31, available in wrought, extruded and cast shapes. It is weldable, can be formed into complex shapes, is heat treatable to a T 6 condition and has a base corrosion resistance considerably better than any previous magnesium alloys. HK 31 has been used as the basic structural metal for the major structure of a ramjet engine, joints being made by fusion welding, resistance welding, riveting and bolting.

The two most promising titanium alloys for elevated-temperature service, both now in limited production, are A 110-AT, an aluminum-tin composition, and 6Al-4V, an aluminum-vanadium alloy. Time will tell whether they will prove to be only interim alloys or long-term members of the titanium family. In any event, it appears that commercially pure titanium will eventually come to hold the same position as a structural metal that commercially pure alumi-

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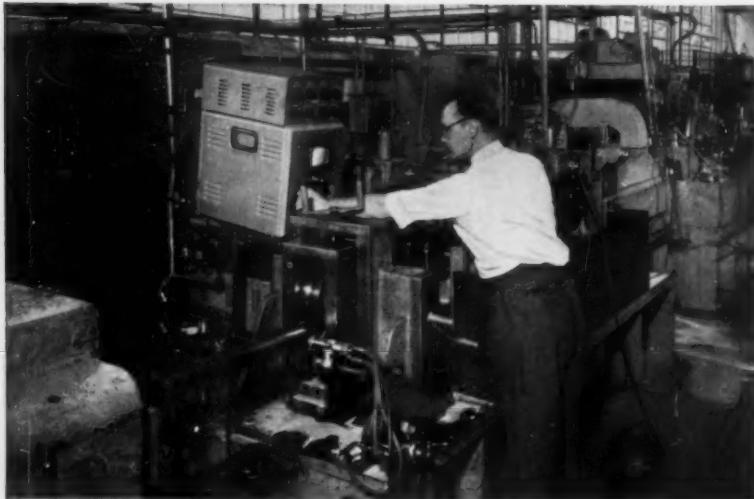
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num holds today — primarily a base material upon which to build.

The 6Al-4V alloy, only recently available in sheet form, is an alpha-beta alloy that is heat treatable at room-temperature strength levels as high as 175,000 psi. ultimate. It is weldable and has been produced primarily in the form of bars and forgings for turbojet compressor applications. It retains sufficient strength, heat treated, at temperatures up to 1000° F. to make it the most attractive material yet known in the moderate temperature range from a strength-weight standpoint.

Clearing away many of the publicity claims for titanium alloys, it appears that three factors now limit their use at temperatures above 1200° F.:

1. Microstructure of the heat treatable alloys currently available is unstable and is susceptible to the formation of brittle phases.
2. Tendency of titanium to absorb atmospheric gases such as oxygen and nitrogen makes it excessively brittle.
3. At 1200° F. the strength of titanium alloys decays to unacceptable levels, despite their acknowledged melting point of approximately 3000° F.

ARTHUR H. ALLEN

## Surface Tension of Liquid Metal

Digest of "The Relationship Between the Surface Tension of Liquid Chromium-Nickel Alloys and Some Properties in the Solid State", by O. S. Bobkova and A. M. Samarin, *Investiya Akademii Nauk S.S.R.*, No. 2, February 1954, p. 52-59.

**A**N ATTEMPT was made to correlate the surface tension of liquid chromium-nickel alloys containing small amounts of boron or titanium or both with the impact strength, hardness and nonmetallic inclusion content of the solid metal. Since the fluidity test is simply determined in most commercial laboratories it was useful to check the variation of surface tension with fluidity of the molten metal.

The fluidity, of course, not only depends on the surface tension of



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## Surface Tension . . .

the molten alloy but also upon the pouring temperature. It was assumed, however, that if the alloy is heated to the same level above the liquidus line the fluidity will be a function of its surface tension. A fluidity determination was carried out for each alloy by pouring the molten metal into a U-shaped mold. The results showed a direct relation between fluidity and surface tension of the alloys for heats melted in an 88-lb. capacity induction furnace and poured at 2695° F., and for heats melted in a 15-lb. induction furnace and poured at 2785 to 2860° F.; and also for heats melted in the same furnace but poured at 3040° F. In general, the fluidity increased with decrease in surface tension.

Additions of boron in quantities up to about 0.22% produced an increase in surface tension in alloys containing about 0.24% titanium. The addition of boron to titanium-free alloys, however, produced a decrease in the surface tension.

A great degree of scatter was found in the results of the hardness and impact tests in both the as-quenched and aged alloys. There was a trend, however, for the impact strength to be lower for the alloys of higher surface tension. Thus, the addition of 0.02% boron to a titanium-free alloy was found to increase the impact value. On the other hand, factors which bring about an increase in surface tension brought about an increase in hardness.

The shape and distribution of inclusions in a metal are governed by the value of the interfacial tension at the interface of the inclusion and molten metal. Inclusion counts showed that as the surface tension of the alloys increased, the inclusion content increased. The counts were carried out at a magnification of 300× and the results were checked by determining the weight of inclusions present by separating them from the metal by anodic dissolution of the alloy. Titanium-free alloys melted with an addition of boron contained a smaller number of inclusions which were much coarser. The inclusion content has an effect on the fluidity in that an increase in the content of non-metallic inclusions with increasing

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## Surface Tension . . .

surface tension will contribute to a decrease in fluidity.

The surface tension of the alloys was measured using the maximum bubble pressure method. Purified argon was passed through a quartz tube about 1.3 to 2.5 mm. in diameter and the pressure necessary to form a gas bubble in the metal was measured by a manometer. The surface tension was calculated from the average maximum pressure during the release of four or five bubbles using the standard formula.

W. A. MORGAN

## Calculating Force and Torque in Cold Rolling

Digest of "A Graphic Solution of the Cold Rolling Problem When Tensions Are Applied to the Strip", by G. Lianis and Hugh Ford, *Journal, Institute of Metals*, Vol. 84, April 1956, p. 299-305.

THE PROBLEM of predicting roll force and torque in cold strip rolling has been studied in several recent investigations. Most of the recommended solutions, however, possess certain disadvantages; either they are conveniently rapid but have a limited range of accuracy, or they are reasonably accurate but require substantial knowledge and experience and are more time consuming. The trend in modern cold rolling practice is increasingly toward tandem rolling, and in these circumstances an accurate and rapid method of calculation is needed for determining tension rolling behavior. Previously published nomographs apply only to rolling without tension and omit the effect of elastic stresses. A nomographic method which includes strip tension is a useful development. This paper not only gives accurate results for roll force and torque, but also reduces the calculations to a series of mechanical operations performed with pencil and straight edge.

The nomographs were calculated from previously published equations of Bland and Ford. The information fed into these equations consists of: (a) the basic yield stress curve connecting the compressive yield stress in plane strain with percentage or

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# Tool Steel Topics



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## BETHLEHEM TOOL STEEL ENGINEER SAYS:



*Air-Quenching Adds  
to Life of  
Hot-work Tools*

Most hot-work tool steels can be hardened by quenching in oil or air. Because of convenience in handling, and in order to avoid excessive scaling, many hot-work tools are oil-quenched. However, air-quenching is better practice because air-quenched tools have lower residual stresses than tools which have been liquid quenched. Since heat-check failures develop from surface stresses produced in service, the presence of residual stresses in the tool itself can lead to premature failure. Tools with low residual stresses are best suited for long service life on hot-work applications. That's why air-quenching is usually considered the most practical procedure for hot-work tools.



## Putting the Bite in Chisel Steel

At Stanley Tool's Atha Plant, Newark, N. J., dies of Bethlehem Lehigh H tool steel are used in trip hammers of this type to forge cold chisel blades. Lehigh H, our special-purpose high-carbon, high-chromium grade, is ideal for this type of application because of its excellent wear-resistance and adequate red hardness.

## INJECTION MOLD OF DURAMOLD B *Pops Out Plastic Poppit Beads*

This injection mold, containing 120 cavities, is used in an 8-oz injection machine to produce one size of the popular polyethylene Poppit Beads. The mold is made of Bethlehem Duramold B tool steel, and was produced by R. A. Koegl Stamp & Die Works, Hillside, N. J., from steel supplied by Ackerlind Steel Co., Inc., New York.

Duramold B is an oil-hardening, chromium-type of plastic-molding die steel, with an addition of boron. In heat-treatment, it develops a surface hardness of Rockwell C62.

Duramold B is ideal for long service life because of its high core-strength and

resistance to wear. Toolmakers are sure to like it because it can be annealed to a hardness of 100 max Brinell, which permits easy cold hobbing, even where deep or large cavities are used.

### Typical Analysis

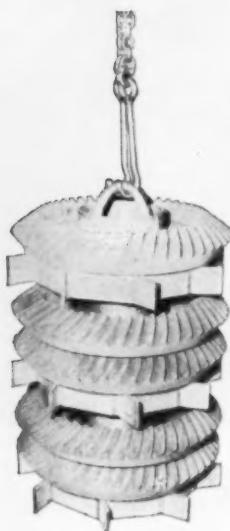
|                 |                |
|-----------------|----------------|
| Carbon 0.07     | Manganese 0.30 |
| Silicon 0.15    | Chromium 1.00  |
| Molybdenum 0.25 | Boron added    |

To order a trial piece of Duramold B, or obtain detailed information about this or any other grade in Bethlehem's complete family of tool steels, simply get in touch with your Bethlehem tool steel distributor.

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## Cold Rolling . . .

fractional compression of the strip, (b) the coefficient of friction between roll and strip, values of which have been measured for a large number of lubricants, various strip materials, and roll finishes, (c) the dimensions of the pass, namely, the roll radius, the entry strip thickness, and the exit strip thickness, (d) the strip tensions expressed as stresses.

It is not necessary to understand the mathematical relationships involved to use these nomographs.

A detailed description of the nomographs and their application is provided and a comparison is made using the nomographs with various experimental results and with more accurate calculations. From these it is shown that the nomographs cover the practical range of cold working conditions with a high degree of accuracy.

W. W. AUSTIN

## New Method of Degassing Liquid Steel

Digest of "The Treatment on a Large Scale of Molten Steel Under Reduced Pressure", by Fritz Harders, Helmut Knuppel and Karl Brotzmann, *Stahl und Eisen*, Vol. 76, Dec. 27, 1956, p. 1721-1728.

THE DORTMUND-HORDER HUTTEN-UNION has, for a number of years, carried out development work to use "reduced pressure" as a new tool of steel metallurgy.

The treatment of liquid steel under reduced pressure results in appreciably upgraded properties, as previously reported in the technical literature. However, equipment available for vacuum treatment was limited in size and did not lend itself to operation on a large scale. Bochumer Verein, however, developed an apparatus to cast forging ingots, weighing up to 150 tons, in vacuum where freedom from impurities is of paramount importance. The process is described in Arthur Tix's article in June 1956 *Metal Progress*.

The theoretical basis for successful treatment of steel under reduced pressure is found in our ability to remove elements (especially gases) whose solubility in liquid metal is pressure-dependent. (Cont. on p. 186)

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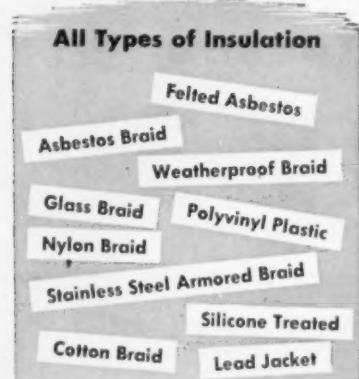
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## Degassing Steel . . .

The addition of alloying elements prior to vacuum treatment can have a significant influence on degassing characteristics. Likewise, the presence of slag and refractories affects the reactions taking place.

A pilot plant was built to determine the economy of vacuum treating liquid steel in large quantities on a *continuous* production scale rather than heat-by-heat, as described by Mr. Tix. A "vacuum-lifter" is suspended from a mobile platform, carried by a crane. The lifter is lowered into the bath, and quantities of about 4 tons of molten steel are successively sucked into the reduced pressure chamber and degassed until the entire heat in the bull ladle has reached the predetermined degree of cleanliness. The liberated gases are carried off.

Of especial interest was the manner in which the degassed portion of the metal mixes with the steel in the ladle on being released from

the vacuum chamber. It was found that, on treating an 80-ton heat of basic openhearth steel, the degassed metal collects primarily on the bottom of the large ladle and that after about 30 partial treatments the gas content of the entire melt was substantially eliminated.

It could be shown that even low-carbon steels when treated on a large scale showed very low oxygen contents (between 0.003 and 0.006%, or one third the original value). Four tons of molten steel can be fully degassed in less than 1 min. Because of the vigorous boiling action caused by rapid degassing, the treatment chamber must be sufficiently large.

Deoxidizers and denitrogenizers as well as those alloying elements which have a higher affinity for oxygen than for iron, should be added only after the degassing operation is complete. To compensate for temperature losses during treatment the vacuum vessel should be heated.

The experimental heats of vacuum degassed steel were primarily

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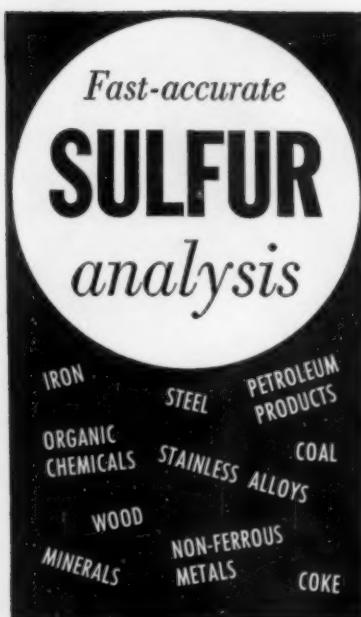
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## Degassing Steel . . .

used for large forged crankshafts which, upon ultrasonic testing, showed no internal discontinuities. Segregation, too, was found to be minimized by vacuum degassing, and deep etching revealed the absence of the microcracks usually encountered.

Highly stressed closed-die forgings for the automotive industry were processed from vacuum-degassed heats without scrap due to metallurgical causes. It also appeared that crack sensitivity was markedly reduced.

Based on the very encouraging results obtained in the large-scale experiments, vacuum degassing is now part of steel production practices, where an 80-ton heat can be successfully treated in 30 min. The primary advantage of the steels is their high degree of cleanliness and uniformity of superior surface quality.

The absence of any reaction between trace elements and oxygen

permits a full utilization of their potentialities for enhancing the quality of steel. Incidental beneficial effects of vacuum degassing are the better machinability reported and the absence of impurities in the grain boundaries which improves resistance to corrosion and amenability to surface treatments depending on diffusion.

The production of both mild and alloy steels having extra low carbon and oxygen is now, therefore, a commercial reality.

HANS HEINE

## Analysis of Nitrides in Steel

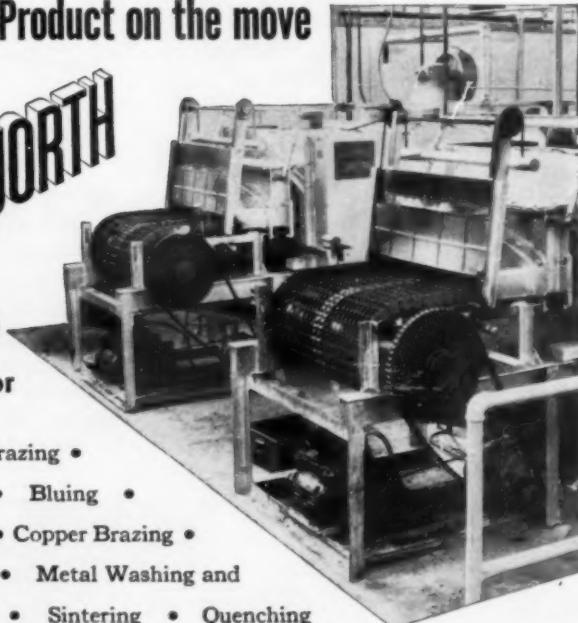
Digest of "The Behavior of Nitrides in Steels During Chemical Analysis", by P. Tyou, J. Vanstiphout and M. Lacombe, *Review Universelle des Mines*, Vol. 9, December 1956, p. 641-652.

MOST NITRIDES in steel cannot be estimated separately. Aluminum nitride is an exception, since the amount of nitrogen in the residue

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# 39<sup>th</sup> National Metal Exposition 2<sup>nd</sup> World Metallurgical Congress



In the whole, wide, wonderful world of metals, for one fast-moving, action-packed week, Chicago will be world headquarters for metal men.

From wherever metals are made . . . from wherever metals are used . . . from all parts of the United States and around the free world, the responsible men of metals will move into Chicago the week of November 4, 1957.

Engineers and scientists . . . executives and production experts . . . the responsible men of metals will be in Chicago to see the 39th National Metal Exposition — the best, the biggest, the most important Metal Show of them all. Hundreds of manufacturers will place their best products and operating processes and equipment on display in the vast International Amphitheatre and New Exposition Halls. This great Exposition will make show history . . . will make metals history.

And this is only half the story. World authorities on metals . . . outstanding scientists from the United States . . . again, the responsible men of metals will be speakers at the 2nd World Metallurgical Congress and at the 39th National Metal Congress. Technical and practical sessions will begin on Saturday, November 2, and run continuously through Friday, November 8. Never before has such an array of metals engineering and scientific talent been assembled on so vast a scale . . . engineering developments of world-wide impact will be presented for all to hear and digest and discuss.

You will want to attend this great event, this world metals week in Chicago. Your organization may well wish to send management, engineering and sales representatives. Make the first move now — write for hotel reservation forms.

## AMERICAN SOCIETY FOR METALS

*The Engineering Society for the Metal Industry*

7301 Euclid Avenue

Cleveland 3, Ohio

Cooperating Societies: Metals Division, American Institute of Mining, Metallurgical and Petroleum Engineers . . . the Society for Non Destructive Testing . . . the Industrial Heating Equipment Association.

## Exhibit Space Available

Hundreds of manufacturers have reserved Metal Show space, but there are good locations still available in the vast new exposition halls of the International Amphitheatre. If the metalproducing or metalworking industries are your market, don't miss this show — write for display information now.



## Analysis of Nitrides . . .

obtained from the attack by bromine and soluble in caustic soda can be established. Various authors have proposed classifying the nitrides formed in steel according to their analytical behavior. The method of H. F. Beeghly is reviewed in detail because it is the most exhaustive and takes into account the effects of heat treatment on the distribution of nitrogen.

The literature survey is followed by the experimental results obtained in this work — first on aluminum and silicon nitride and second on titanium nitride.

Under certain circumstances aluminum nitride is partially affected by hydrolysis during anodic dissolution. This was shown by the fact that the total nitrogen determined from the residues of anodic dissolution was not identical with that determined from the steels. When the same steels were heated to 2370° F. for one hour in argon and quenched, the reproducibility of results was much better and it seems that the thermal treatment gives a more stable form of nitrides. However, the better reproducibility may possibly be ascribed to the absence of traces of graphite. As has been found in cast irons, graphite seriously complicates the estimation of

nitrogen in ferrous metals. The solubility of aluminum nitride in acids and alkalis and its elimination by chlorine were also studied. Silicon nitride in a low-silicon steel is soluble in dilute acids. However, in 1.75 to 2.25% Si steel, not aluminum killed, it appears that the silicon nitrides are insoluble in dilute acids or alkalis but may be decomposed by concentrated  $H_2SO_4$  in the presence of  $K_2SO_4-CuSO_4$ .

The author's results may seem, by deductive reasoning, to differ from those of the seven or eight papers reviewed. They may not be contradictory, however, since they refer probably to different compounds. Very possibly, many different aluminum and silicon nitrides are formed in the steel, depending upon the amount of these elements present.

Most other elements including columbium, tantalum, vanadium, titanium and probably chromium, nickel, molybdenum, tungsten and copper, form insoluble nitrides which are contained in the residue. However, certain heat treatments will render all nitrides soluble except titanium nitride.

The analytical properties of insoluble nitrides and the methods of estimation of metallic elements present in the residues are described in some detail.

For titanium, the methods of acid solution used had no effect on the total titanium determined. All the titanium in the residue was in the form of compounds, but the amount of titanium as oxide was extremely small compared with the total titanium. Consequently the titanium must be in the form of carbides or nitrides. It would appear that the titanium was in the form of carbonitrides  $Ti(C,N)$ . No free carbide or nitride of titanium was observed by X-ray diffraction, but it was also impossible to ascertain the presence of  $Ti(C,N)$  since the space lattice of the latter is not known with certainty.

It is concluded that after heating and quenching from 2370° F. the insoluble nitrogen in the residue represents titanium nitride. The nitrides rendered soluble by the above treatment in the steel studied were provisionally thought to be nickel nitrides since no vanadium, columbium or tantalum was present.

H. P. TARDIF

**MACHINE WAYS**

**FLAME HARDENED**

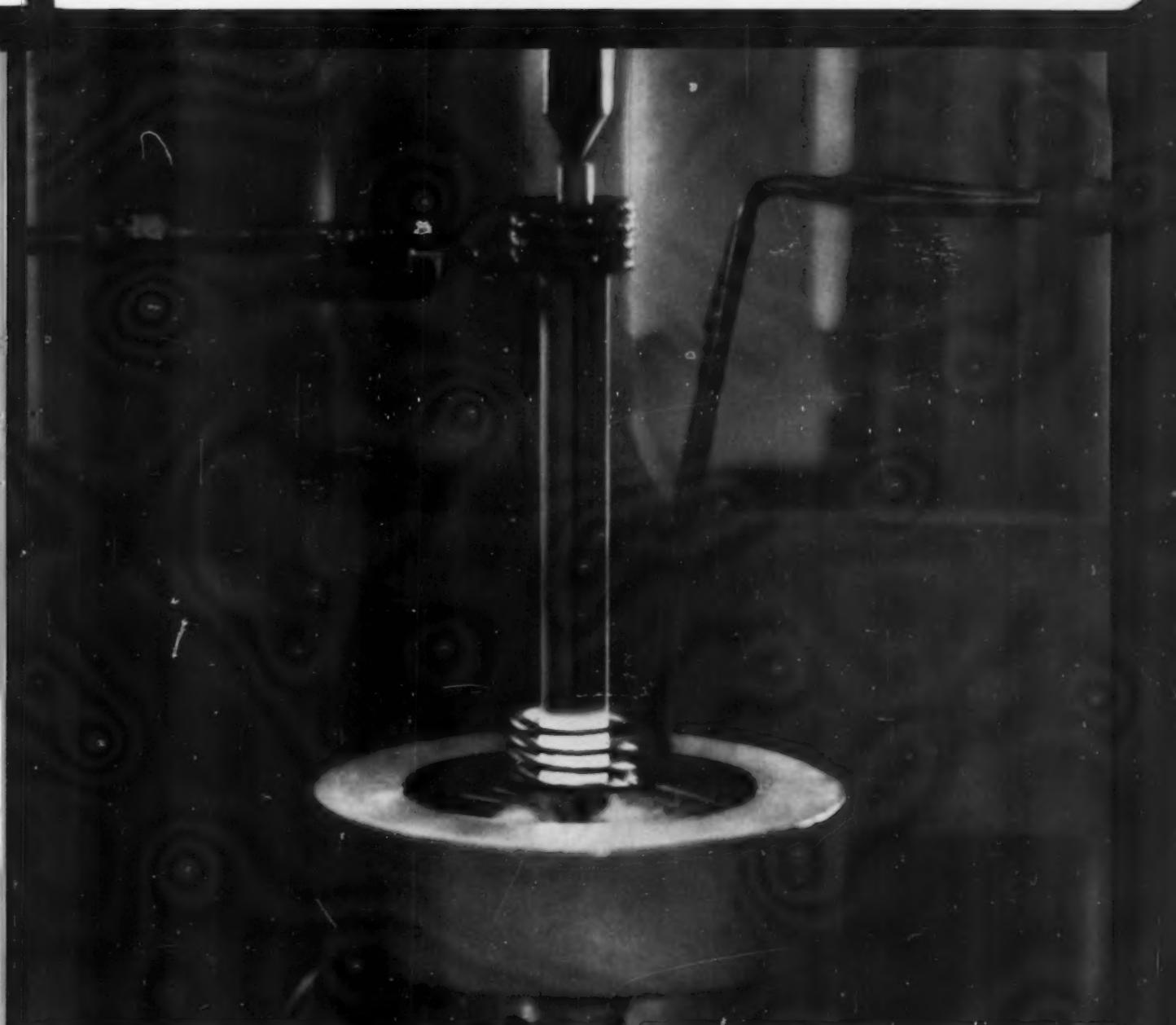
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WRITE FOR LITERATURE

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Ketos shaft being induction hardened to Rockwell 55-56, while ends remain soft for final machining. Photographed at Control Instrument Co., Inc., Brooklyn, N. Y.

## KETOS has wide hardening range with minimum volume change...

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## Nickel-Base Alloys for High-Temperature Use

Digest of "Past, Present and Future of High-Temperature Nickel-Base Alloys", by F. L. VerSnyder, *Journal of Metals*, Vol. 8, October 1956, p. 1445-1449.

THE INVENTION of nichrome in 1906 marked the beginning of the use of nickel-base alloys for high-temperature service. However, they did not achieve prominence in this field until World War II.

A majority of the important nickel-base alloys such as nichrome, Hastel-

loy C, the Inconel series, the Nimonic series, some of the Inco series, Waspalloy, Refractalloy, and M-252, contain appreciable amounts of chromium (15 to 20%). Other elements commonly found in these alloys are iron, carbon, cobalt, columbium, molybdenum, tungsten, titanium, aluminum and vanadium. Titanium and aluminum are added primarily to promote precipitation and are usually added together.

The methods used for melting and casting simple nickel-base alloys are similar to those used for steel. The more complex alloys which contain more than 3% titanium plus

aluminum must be vacuum melted for best results. Vacuum melting prevents the formation of titanium nitride and carbo-nitride inclusions which could cause forging and machining difficulties. At present it is being intensively investigated as a production technique for melting nickel-base alloys because turbine buckets and blades made of vacuum melted alloys have exhibited appreciably higher stress-rupture and fatigue strengths than those made of air melted materials.

The majority of the alloys mentioned above are used in the wrought condition and are forged to the desired shapes. However, forging or rolling results in only 50 to 60% recovery from the original ingot. Since a recovery of 90% is possible if the metal is extruded, this technique is being investigated.

Nickel-base alloys are also being considered for high-temperature structural materials since they possess high stress-rupture strength. At present they are being utilized for applications in the temperature range of 1200 to 1600° F., but it is anticipated that this ceiling will be raised. In this respect the future looks promising since the stress-rupture strength can be increased by increasing the complexity of the alloy. However, the major problem is to produce these alloys in large quantities with uniform properties.

The microstructure of nickel-base alloys determines their mechanical properties. The properties are affected by the addition of various elements such as titanium, aluminum, cobalt and many others, which either harden the solid solution phase or cause a second phase to precipitate. The former results in better creep strength whereas the latter raises the stress-rupture strength.

The structural changes resulting from additions to the basic alloys have been studied intensively in an effort to develop alloys suitable for gas turbine rotor blades. The studies revealed that nickel-base alloys have low recrystallization temperatures and are subject to intergranular oxidation in processing. Either of these conditions is detrimental to turbine blades but both conditions can be eliminated by electromachining the blades in the final stages of processing.

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Write for Bulletin 157

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Metallurgist  
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# METALLOGRAPHES

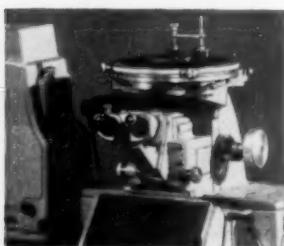
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## Martensite Formation During Arc Welding

Digest of "The Prevention of Martensite Formation During Arc Welding", by Fritz Dechner and Hermann Speich, *Stahl und Eisen*, Vol. 76, Sept. 20, 1956, p. 1249-1251.

**A**RC WELDING TESTS, using hand welding methods, were carried out on several carbon steels varying in thickness from 0.25 to 0.60 in. An annealing torch used to follow the electrode prevented the formation of martensite in the heat-affected zone. Reducing the cooling rate by supplying additional heat with the annealing torch allowed time for the austenite to transform to ferrite and pearlite or transition products rather than martensite.

In order to use this method, it was necessary to establish the time-temperature-transformation curve for the particular steel as well as the cooling curve in the weld area. Since the time-temperature-transformation curves are well known for the steels used in these tests, it was only necessary to determine the cooling curves in the weld areas for the various sheet thicknesses and welding conditions. This was done by temperature measurements using Tempilstiks.

Time-temperature-transformation curves or metallographic examination of the weld area can be used to establish which sheet thicknesses in each steel require the annealing treatment to avoid martensite formation. The distance of the annealing burner depends on the welding speed and the transformation time of the steel. For example, when welding an St. 70 (S.A.E. 1054) steel (transformation time of 2 sec. at 1060° F.), the annealing distance must be 1.8 in. for a welding speed of 35 in. per min.

Tests carried out showed that this process of preventing martensite formation was not feasible with hand welding methods due to fluctuations in temperature so great that the martensite transformation occurs in some areas before the annealing heat takes effect. In automatic arc welding, it is possible to delay the cooling sufficiently to allow the austenite to transform to ferrite and pearlite if the annealing torch is properly and accurately adjusted.

R. C. SHNAY



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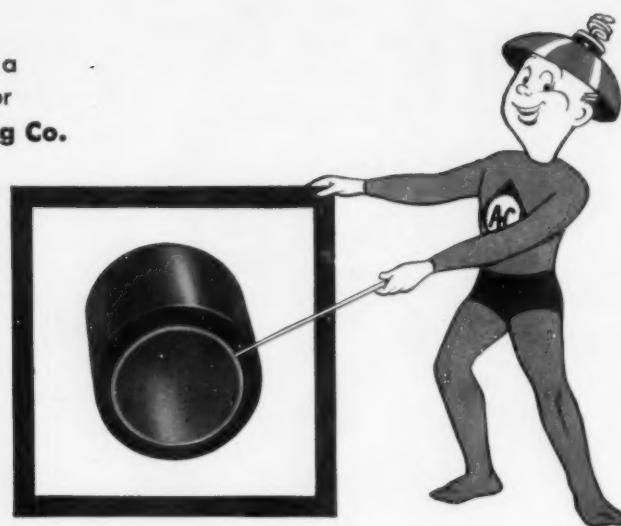
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**Mr. Hi Frequency** does a  
Surface Hardening Job for  
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## Boosts Bolt Sales 300%

**Jambor had trouble.** They were making a top-grade king bolt with excellent wearing qualities, but it had one little drawback — *it was "file soft."*

### Mr. Hi Frequency to the Rescue

To remedy the situation, Jambor switched to a higher carbon steel and surface-hardened the bolts with Allis-Chalmers electronic induction heaters. Mr. Hi Frequency's rapid and selective method of surface hardening produced amazing results. Sales went up a whopping 300%. Material costs dropped 10%.

*It could happen to you.* If your job is one of hardening, annealing, soldering, brazing or melting, it will pay you to consider Allis-Chalmers induction heating. Chances are this most advanced method of applying heat will boost your production, decrease costs and improve quality just as it has in hundreds of applications. For complete information, see your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

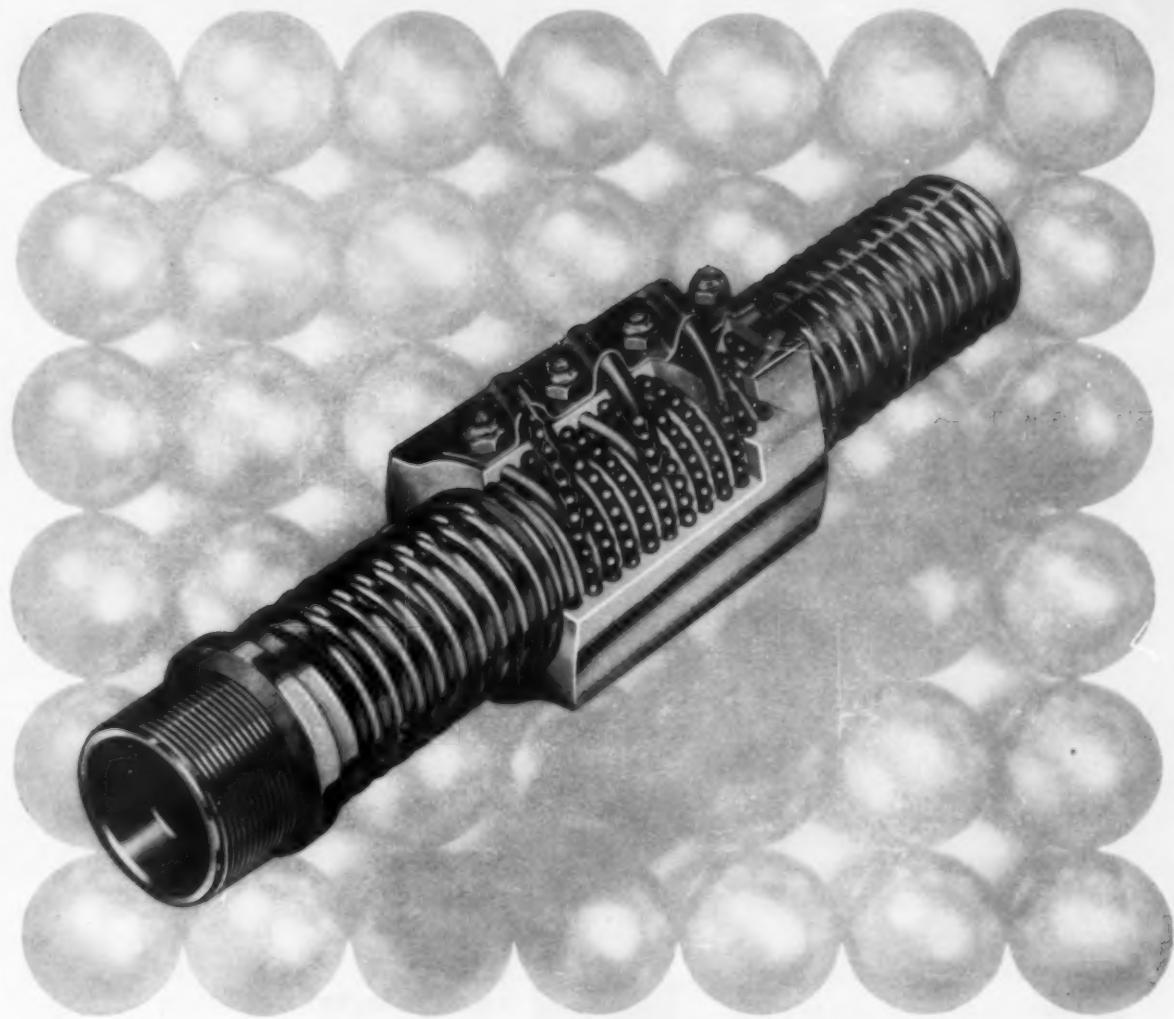
White line indicates hardened steel. A uniform case depth of .060 with Rockwell hardness of 60 to 62 is obtained. (Black wrapper was used in photo to emphasize hardened area.)



Jambor uses a 20-kv Allis-Chalmers induction heater. The work coil and quenching ring were specially designed for the specific job by Allis-Chalmers.



# ALLIS-CHALMERS



## how Vacuum Metals' **FERROVAC** boosts ball bearing screw life up to 400%...

Ball bearing screw assemblies, first used in automobile steering mechanisms, are now found in such critical applications as the actuation of landing gear and control surfaces of aircraft and guided missiles. And it was in tough jobs like these that the assemblies failed in fatigue. Then a leading manufacturer tried vacuum-melted FERROVAC® for the balls — and service life rose as much as 400% over the original life. Here's why...

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**Only Vacuum Metals gives you one-source service** — Vacuum Metals Corporation, Division of Crucible Steel Company of America, provides a fully integrated service from melting and casting through mill rolling and nationwide distribution of finished mill products. And you can get not only small experimental lots, but now, thanks to our new 2500 lb. induction furnace — the nation's largest — you can also get large-scale continuous production quantities of vacuum-melted metals. If you have an application which these unique metals may improve, please write giving full details. *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, New York.*



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An easy-to-prepare single mix powder formula. AnSCO Powdered X-ray Fixer has unusually high capacity, fast fixing characteristics and good hardening properties.

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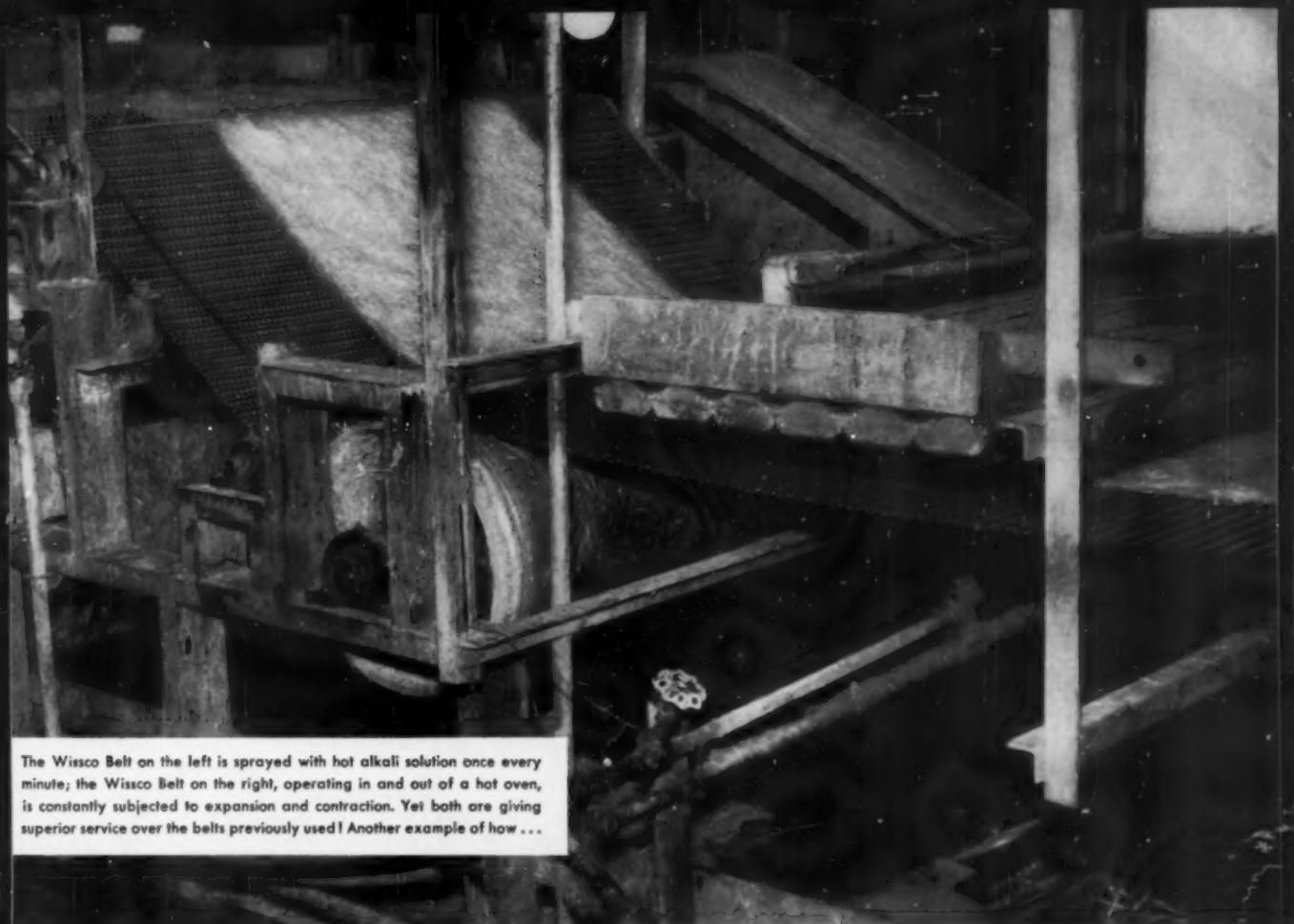
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| LIQUADOL DEVELOPER   | 1 gallon | 5 gallons | 20 gallons | 200 gallons* |
| LIQUADOL REPLENISHER | 1 gallon | 5 gallons | 20 gallons | 200 gallons* |
| LIQUAFIX FIXER       | 1 gallon | 5 gallons | .....      | 400 gallons  |
| POWDERED X-RAY FIXER | 1 gallon | 5 gallons | 20 gallons | 50 gallons   |

\*Supplied in 50 gallon size collapsible rubber drums.

A complete line of AnSCO X-ray products is carried by your local X-ray equipment dealer.

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The Wissco Belt on the left is sprayed with hot alkali solution once every minute; the Wissco Belt on the right, operating in and out of a hot oven, is constantly subjected to expansion and contraction. Yet both are giving superior service over the belts previously used! Another example of how ...

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*The story of Wissco Belts is best told by their users. For instance, Mr. A. B. Paschall, Jr., Plant Engineer of Ferro Corporation's Fiber Glass Division at Nashville, Tennessee, says:*

**"Our Wissco Belts give double the life of the belts we previously used. What's more, they carry our mats through a 110' long processing unit with sharp-shooter accuracy."**

The belts help process fiber glass mats used to make automobile bodies, boats, ultra-modern furniture and many other items. During their manufacture, the mats pass over four different Wissco Belts; at the end of the operation, the mats must pass exactly between two stationary knives which trim the sides of the mats to the proper width. "A wandering belt would cost us dearly in this operation," Mr. Paschall says. "But our Wissco Belts handle it perfectly."

As for the durability of Wissco Belts, Mr. Paschall has this to say: "Two of our belts are subjected to severe abuse. The 'wet' belt is sprayed with hot alkali solution once every minute. For this, we use a Wissco Belt made of stainless steel. The oven belt is subjected to heat rather than chem-

ical abuse, so we use a Wissco Carbon Steel Belt. We have found that this belt has a satisfactory degree of expansion and contraction, and requires little handling of the take-up mechanism designed to care for slack development.

"Service? Well these Wissco Belts have already been in operation for over three years. But the belts we previously used had to be replaced in a year and a half or less," Mr. Paschall concludes.

Long service life . . . superior accuracy . . . minimum maintenance. Wissco Belts can give you all these important savings, too. Write today for complete details on how you can take best advantage of Wissco Belts in your own normal or high-temperature processing operations.

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...A Notable Coincidence

## The Second World Metallurgical Congress

### RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff card-board; maximum dimensions (4 by 18 in., 10 by 45 cm.). Heavy solid frames are unacceptable.

Entries should carry label on the back of the mount giving:

#### Classification of entrants

Material, mount, magnification.

Any special information as desired.

The name, company affiliation and postal address of the exhibitor should be placed on the back of the mount.

Entrants living outside the U. S. A. should send their micros by first-class letter mail endorsed "Photo for Exhibition—May be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 15, 1957, either by prepaid express, registered parcel post or first-class letter mail, addressed:

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Class 1. Iron and steels.

Class 2. Stainless steels and heat resisting alloys.

Class 3. Aluminum, magnesium, beryllium, titanium and their alloys.

Class 4. Copper, nickel, zinc, lead and their alloys.

Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 6. Metals and alloys not otherwise classified.

Class 7. Series showing trans-

sitions and changes during processing.

Class 8. Welds and other joining methods.

Class 9. Surface coatings and surface phenomena.

Class 10. Results by unconventional techniques (other than electron micrographs).

Class 11. Slags, inclusions, refractories, cermets and aggregates.

Class 12. Color prints in any of the above classes. (No transparencies accepted.)

### AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of \$100, will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1958 if so desired.

## The Twelfth

### Metallographic Exhibit

Chicago, Illinois, November 2 to 8, 1957

# New trends and developments for design engineers . . .

## How to combat abrasion by "wearproofing" critical components with Carboloy® cemented carbides

This is what abrasion can do to a piece of steel:



FIGURE 1 — Abrasive damage caused by pivoting arm on pill press.

There is some disagreement among scientists over how the abrasion process actually works. But there is universal agreement among designers over the havoc it wreaks: it shreds, gouges, galls, pits, grinds, and cuts the surface of a material. It ruins equipment, causes excessive repairs and downtime . . . and wastes literally millions of dollars annually in almost every industry.

There is no practical way to eliminate abrasion on most applications. It occurs wherever there is friction between two materials.

There is, however, a simple way to slow down its ravages: "Wearproof" critical machine and product parts with harder, smoother materials.

The hardest materials designers have available are cemented carbides. Carboloy cemented carbides range up to 93 on the Rockwell "A" scale . . . compared to only 84 for SAE 1095 heat-treated carbon steel. Carbides can outwear steel by 10, 50, or as much as 100 to 1.

As for smoothness, cemented carbides take so fine a finish they are in widespread use as gage-blocks accurate to millionths of an inch.



FIGURE 2 — Gage blocks made of cemented carbide. Surface finish of .0005".

This combination of extreme hardness and smoothness has lead to thousands of applications for cemented carbides throughout industry.

For example, nozzles handling

abrasive liquids from centrifuges at 1200 psi (Figure 3) are made entirely of Carboloy cemented carbide. The carbide provides a service life of 8 to 12 months — twice that of the rubber-lined nozzles previously used.

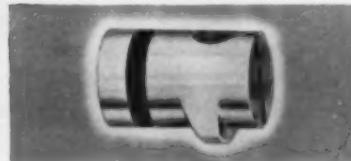


FIGURE 3 — Carbide nozzles on Merco Centrifugal Co. equipment withstand separating forces 9000 times that of gravity.

In the textile industry, carbide guides for high-speed braiders (Figure 4) wear as long as 6 years — compared to an average of 2-3 weeks for conventional hardened steel. The carbide provides more uniform finish, and easily resists the abrasive synthetic fibers.



FIGURE 4 — Carbide stop eyes for high-speed Mossberg brazier.

In subsurface pumps for oil wells, Carboloy cemented carbide balls and seats (Figure 5) resist acids and abrasive sands. They outlast steel up to 20 times, and the balls maintain sphericity under the severest conditions of impact and pressure.

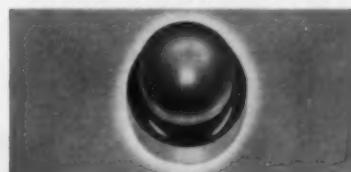


FIGURE 5 — Carbide balls and seats for oil-well pumps.

For power socket wrenches, sockets equipped with Carboloy cemented carbide inserts (Figure 6) outlast ordinary materials 15 to 20 times. The carbide stops product damage from slippage, cuts socket replacement costs.



FIGURE 6 — R. J. Williams power socket wrench uses carbide inserts in sockets.

From the designer's viewpoint, one of the major advantages of carbides is their versatility.

Carbides can be produced in a broad assortment of sizes and shapes — hence there is almost no limit to their design possibilities. And they are available in a wide range of grades — hence almost any combination of physical properties can be produced.

Carbides have high compressive strength — 1 to 6 times that of steel. They have tremendous resistance to twisting and deformation under load — 2½ to 3 times that of steel.

These and other unique physical properties are the reasons that carbides are now in use throughout industry, protecting valuable equipment from premature scrapping due to wear. If you have a wear problem — whether abrasion, erosion, friction, or corrosion — carbides may well be the answer.

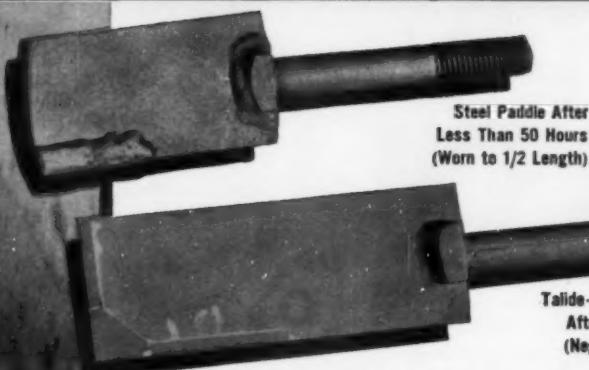
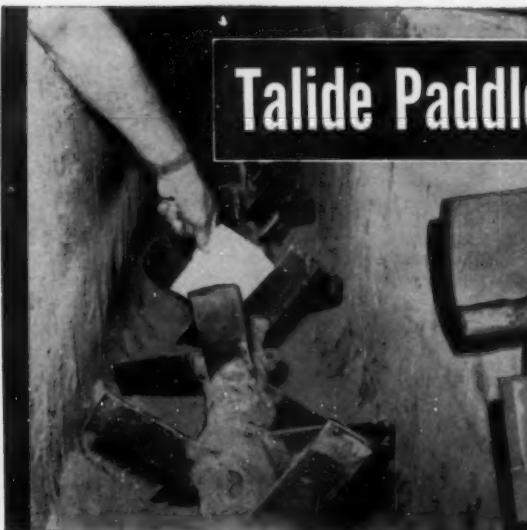
For design assistance, or technical data on Carboloy cemented carbides, write: Metallurgical Products Department of General Electric Company, 11167 E. 8 Mile Road, Detroit 32, Michigan.

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# Talide Paddles Last 50 Times Longer!



## HARDEST MAN-MADE METAL!

**TALIDE METAL**, a tungsten carbide of superior quality, is harder, stronger, and more resistant to abrasion than any other metal. Properly applied, it gives superior service on applications where wear, heat, strain, and shock are destructive to other metals.

- **ABRASION RESISTANCE**—Up to 100 times that of steel.
- **COMPRESSIVE STRENGTH**—Higher than all melted, cast or forged metals and alloys.
- **RESISTANCE TO DEFORMATION**—2 to 3 times greater than steel.
- **HEAT RESISTANCE**—Resists oxidation and thermal shock up to 1500° F.
- **THERMAL EXPANSION**—Less than half the rate of steel, "creep" is negligible.
- **FRictional RESISTANCE**—Lower than steel, non-galling, "slippery" properties higher.

ALL TALIDE METAL grades are made in latest type vacuum electric furnaces by precision methods under rigid control. A wide variety of shapes and sizes can be supplied—up to 25" in diameter, 100" in length, and 5000 pounds by weight. Parts can be supplied to any grit finish required down to one micro-inch. The physical properties of the most commonly used grades are listed below. Other grades are available for specialized applications.

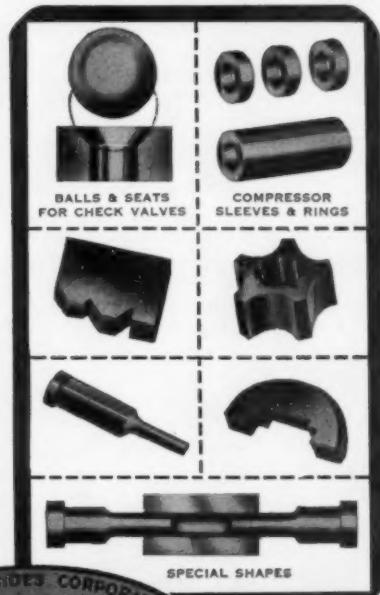
### PHYSICAL PROPERTIES OF TALIDE METAL (P. S. I.)

| Application  | Operation    | Talide Grade | Rockwell "A" Hardness | Specific Gravity (Density) | Transverse Rupture Strength | Compressive Strength | Co-Efficient of Thermal Expansion | Modulus of Elasticity (Deflection) |
|--------------|--------------|--------------|-----------------------|----------------------------|-----------------------------|----------------------|-----------------------------------|------------------------------------|
| WEAR SURFACE | No Shock     | C-91         | 91.8                  | 14.90                      | 235,000                     | 710,000              | $3.00 \times 10^{-6}$             | 91,000,000                         |
|              | Light Shock  | C-99         | 91.0                  | 14.75                      | 265,000                     | 670,000              | $3.65 \times 10^{-6}$             | 84,000,000                         |
|              | Medium Shock | C-88         | 89.5                  | 14.55                      | 295,000                     | 635,000              | $4.00 \times 10^{-6}$             | 80,000,000                         |
| IMPACT       | Light        | C-85         | 88.4                  | 14.25                      | 315,000                     | 600,000              | $3.75 \times 10^{-6}$             | 77,000,000                         |
|              | Medium       | C-80         | 87.0                  | 13.85                      | 335,000                     | 550,000              | $4.50 \times 10^{-6}$             | 74,000,000                         |
|              | Heavy        | C-75         | 85.0                  | 13.15                      | 355,000                     | 500,000              | $5.00 \times 10^{-6}$             | 70,000,000                         |

Note: Hardness values may vary plus or minus .2 to .3 on individual lots.

Send for new 76-page catalog  
56-G or ask for sales  
engineer to call.

Metal Carbides Corporation  
Youngstown 12, Ohio





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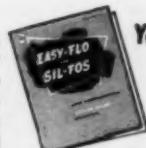
Before, sprocket was machined and hobbed from solid metal, then welded. Now, three stampings are EASY-FLO-brazed to turned hub.

Result—sprocket made stronger in less time, with less metal.



### TAKE TWENTY

BULLETIN 20 tells you why high strength, speed and economy are inherent in EASY-FLO brazing. Also gives Handy information about joint design and fast brazing methods. We'll be pleased to send you a copy.



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# SPECIAL REPORTS ON FINISHING NON-FERROUS METALS

## NUMBER I—Decorative, Corrosion-Resistant Finishing with Iridite

Chromate conversion coatings are well known and accepted throughout industry as an economical means of providing corrosion protection, a decorative finish or a good paint base for non-ferrous metals. However, continued developments are so rapid and widespread that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this digest of current information; to bring you up to date on the many ways in which you can combine salable appearance with durability in one finish at a competitive price advantage. Report II on paint base, corrosion-resistant finishes and Report III on chemically polished, corrosion-resistant finishes are available on request.

First, as a basis for this discussion, a "decorative" finish is considered as any chromate film that is used as a final finish in itself. It may be truly decorative in that its sole purpose is to enhance the beauty of the product. For example, a bright chrome-like finish or a pleasing bronze appearance are among the many effects that can be obtained. It may be functionally decorative in that it reduces reflectivity for camouflage purposes or provides a means of color-coding parts. But, in all cases, the Iridite films protect the metal against corrosive attack.

Iridite finishes are now available for all commercial forms of the more commonly used non-ferrous metals, including zinc, cadmium, aluminum, magnesium, silver, copper, brass and bronze. These films can produce a wide variety of pleasing appearances. The basic colors of the Iridite coatings are grouped below by metals.

**ZINC and CADMIUM:** Metallic bright, light iridescent, iridescent yellow, bronze, olive drab.

**COPPER, BRASS, BRONZE:** Metallic bright, yellow.

**ALUMINUM ALLOYS:** Clear, iridescent yellow, brown.

**MAGNESIUM ALLOYS:** Light brown, dark brown, black.

**SILVER:** Metallic bright.

In addition, many films can be modified by bleaching or by dyeing. Among the dye colors available are various shades of red, yellow, green, blue or black.

Depending upon the metal and the Iridite used, corrosion resistance of clear and bright films ranges from mild passivity to as high as 500 hours in salt-spray; on heavier dark films, salt-spray resistance ranges from approximately 100 to 1000 hours.

It is this combination of decorative and corrosion resistant properties that accounts for the widening use of Iridite finishes. For example, Iridites #4-73 and #4-75 (Cast-Zinc-Brite) make possible for the first time, a combination of lustrous chemical polishing of the as-cast surface of zinc die castings and good resistance to corrosion. Further, in many cases,

### WHAT IS IRIDITE?

Briefly, Iridite is the trademark for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

sizeable savings in the cost of buffing and electroplating are realized.

On many steel parts, a simple system of zinc or cadmium plate and bright Iridite is used instead of more costly electroplated finishes to provide a bright, decorative and protective finish with tremendous savings in material, equipment and labor.

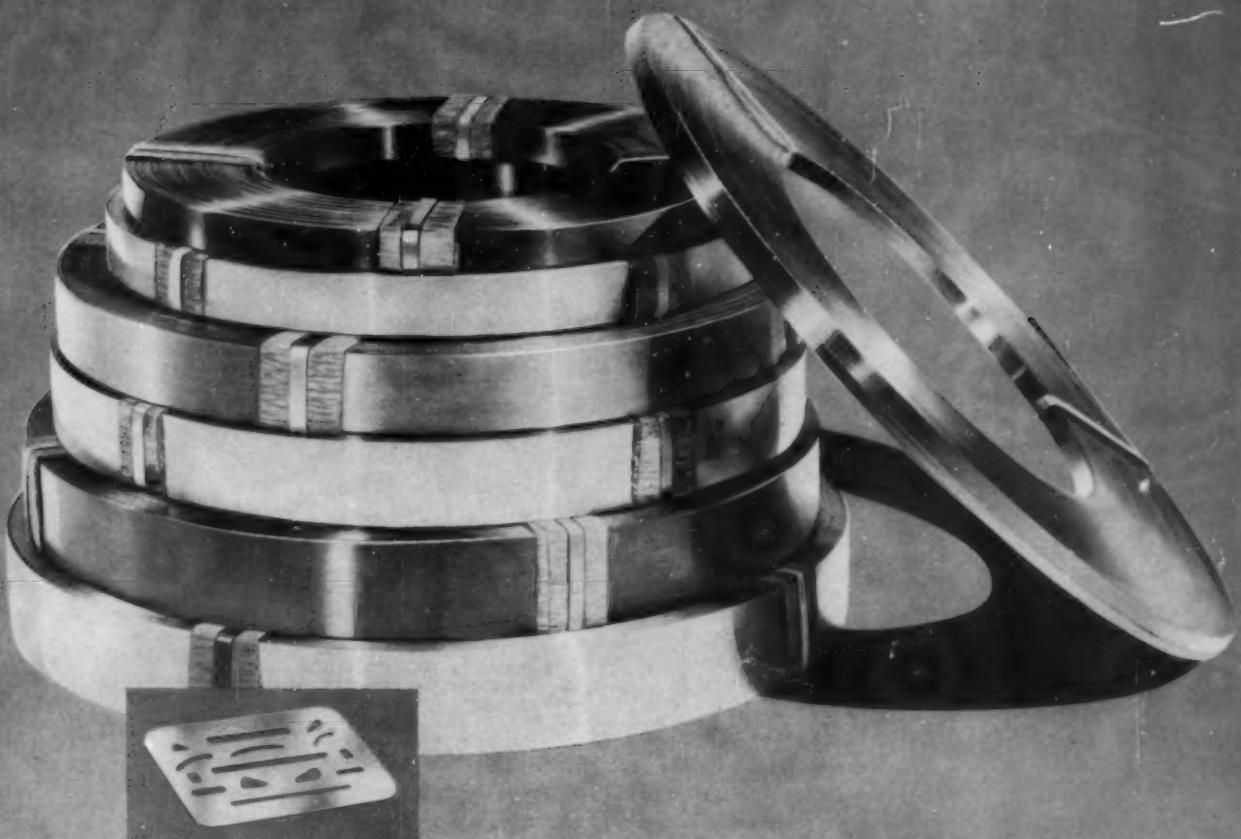
In finishing aluminum, where corrosion resistance or paint adherence is the prime consideration, the aircraft industry has all but abandoned the anodizing process in favor of recently developed chromate conversion coatings, among them Iridite #14 and #14-2 (Al-Coat). These formulations and their method of application can be varied to retain the original metallic appearance while providing acceptable corrosion resistance, or to produce a fully colored brown finish that offers exceptional corrosion protection. Again, time and manpower savings are astounding—one company saved at least \$15,000 a year on maintenance of racks alone and another \$40,000 on materials and labor in only nine months. In addition, of course, hundreds of thousands of dollars are saved by eliminating the need for expenditures for generators, heating equipment and racks.

Iridites are widely approved under both Armed Services and industrial specifications because of performance, low cost and savings of materials and equipment.

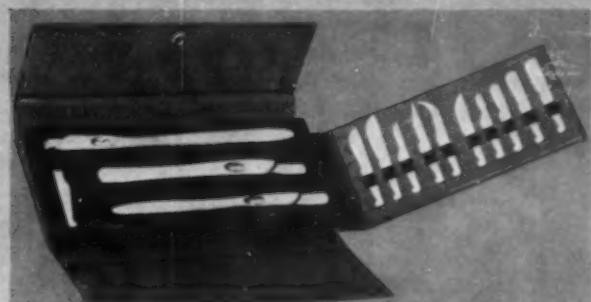
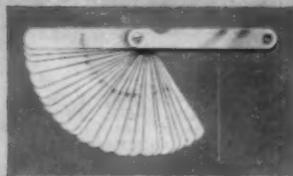
In planning or designing, you should consider the many other characteristics of Iridite finishes which may enter into the specific problem. In addition to having decorative and protective functions, these chromate coatings form an excellent base for organic finishes and bonding compounds. They have low electrical resistance. Some can be soldered and welded. The Iridite film itself does not affect the dimensional stability of close tolerance parts.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product requires the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 E. Monument Street, Baltimore 5, Maryland.

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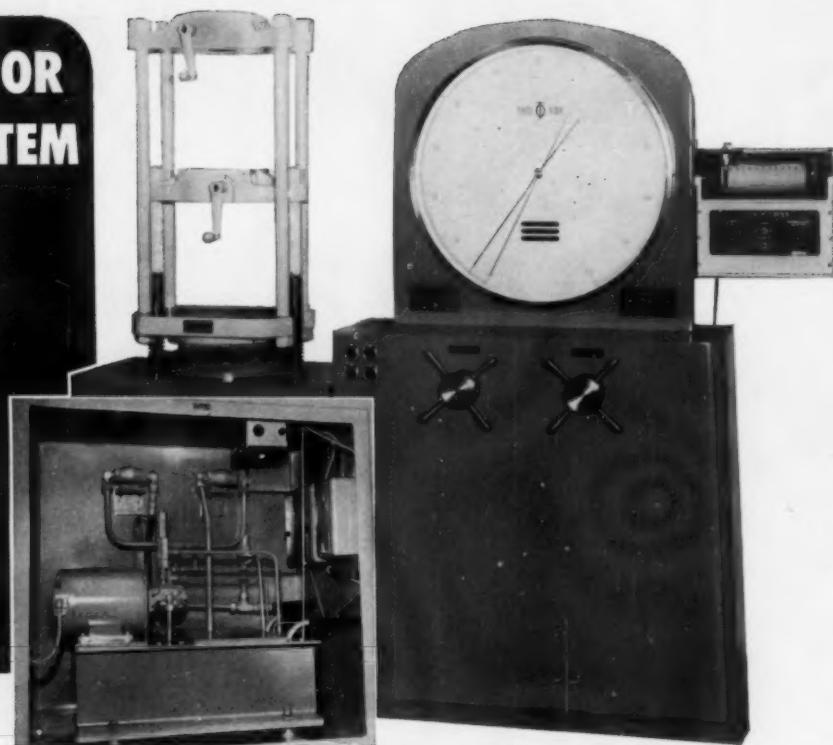
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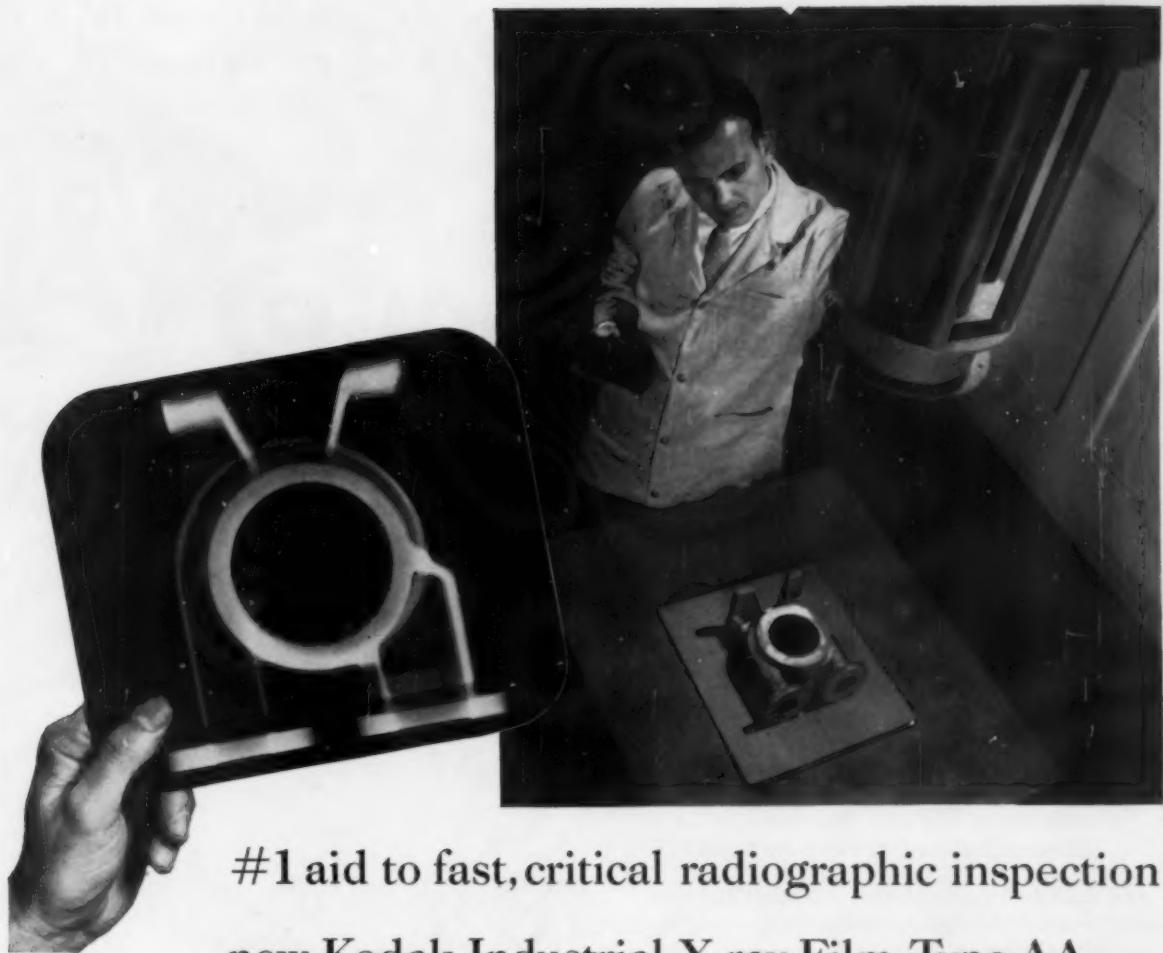
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This film retains all the excellent qualities that made Kodak Type A

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This permits exposure time to be cut as much as 50%. It allows adjustment of the radiographic factors to obtain greater contrast and easier readability.

Kodak X-ray Film, Type AA can multiply your minutes—can extend the usefulness of your present radiographic equipment.

Find out all the ways it can improve your production. Get in touch with your x-ray dealer or Kodak Technical Representative.

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Read what the new Kodak Industrial X-ray Film, Type AA, does for you:

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*Kodak Industrial X-ray Film, Type AA and Type M is now available in 100-sheet boxes wrapped without interleaving paper. Designated as AA-100; M-100.*

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*You name it...*

**Ampco can supply it,  
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**You enjoy design flexibility,  
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Among more than 100 Ampco copper-base alloys is the one you need for

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Call in your Ampco field engineer.  
Write for Bulletin 33.



D-60



**Sand castings** in any size up to 14,000 pounds — and **centrifugal castings** up to five tons—are produced in Ampco foundries.



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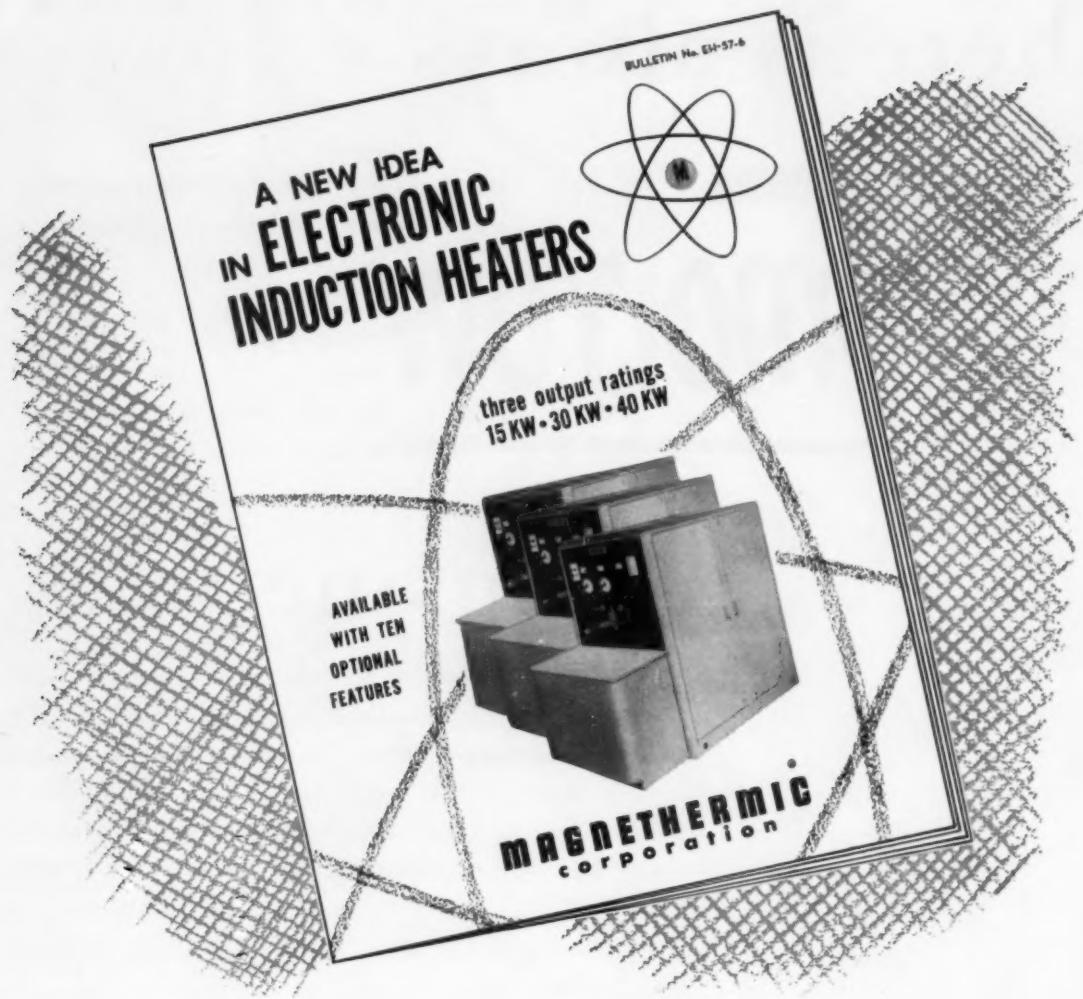
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For the first time, an electronic induction heater can be pinpointed to specific conditions or operation—literally a custom design at reasonable cost.

No two induction heating processes are the same. For optimum performance, each induction heater should be hand tailored to the job. The Magnethermic plan of adding optional features to a standard heater results in a custom design at low cost. Magnethermic's "building block" principle for electronic induction heaters provides the flexibility needed for low unit cost.

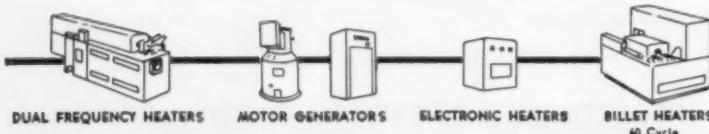
Here are a few of the optional features which can be added to the standard heater:

- Built-in Output Transformer
- Stepless Thyatron Power Control
- Built-in Water Cooling System
- Dust-proof Cabinet and Air Cooling System

All ten optional features and the standard heater are detailed in this new bulletin, available upon request. The bulletin contains ratings, specifications, and such useful data as a frequency selector chart, surface hardening table.

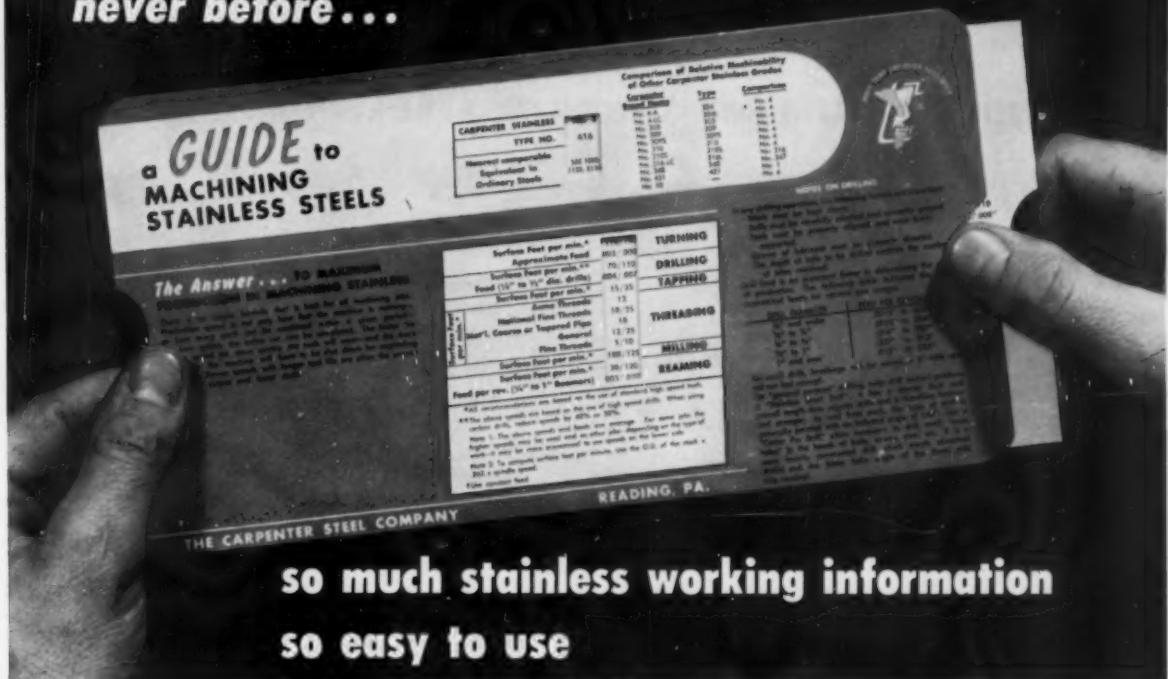
Heaters available from stock in three ratings—15 KW, 30 KW, 40 KW output.

Address your electronic induction heater inquiry to Magnethermic, Youngstown, Ohio.  
New Bulletin EH-57-6 available upon request.



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so much stainless working information  
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## Carpenter's new stainless slide chart is a guide

Here's the newest example—just off the press—of how Carpenter printed information is designed to help you and your men when working with stainless.

Now, right at your fingertips, you can have practical data to help you make the most of every pound of stainless you use . . . quickly answer many time-consuming daily questions.

For the first time, with slide chart ease, accuracy and convenience, you can quickly uncover working information about machining speeds and feeds, for turning, drilling, tapping, threading, milling and reaming. One entire side is devoted to such helpful facts as these—all taken from Carpenter's widely used "Notebook on Machining Stainless Steels".

The reverse side is equally valuable. Completely up-to-date, it gives the relative workability for many stainless grades . . . helps you quickly pinpoint the proper stainless for drawing, forging, heading, swaging, welding, buffing, etc.

For your personal copy, simply drop us a line on your company letterhead. If you'd like some extra copies of this NEW Carpenter Stainless Slide Chart for others in your plant, just tell us.

These formulas are just a sample of the help you can expect from Carpenter's NEW Stainless Slide Chart.

### No. 1 — for obtaining tap drill size:

$$\text{Outside Diameter} \left\{ - \frac{.0130 \times \% \text{ Full Thread}}{\text{Number of threads per inch}} = \text{Drill Size}$$

Example - for  $\frac{3}{8}'' \times 20$  thread:

$$.250 - \frac{.0130 \times 75}{20} = .2013 \text{ or number 7 drill}$$

### No. 2 — for obtaining percentage of thread a given drill will produce:

$$\frac{(\text{Outside dia.} - \text{drill size}) \times \text{number threads per inch}}{.0130} = \% \text{ of full thread}$$

Example - for  $\frac{3}{8}'' \times 20$  thread:

$$\frac{(.250 - .201) \times 20}{.0130} = 75.4\% \text{ thread}$$



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In addition to greater impact strength at elevated temperatures, a tough fine grain structure is produced . . . relatively free of contamination. It is readily castable or extrudable, with minimum microporosity or microshrinkage. It resists corrosion.

Foundrymen prefer TAM Master Alloy for its ease of handling and storing as well as its freedom from obnoxious fuming.



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| 304 416     | 5350 5380  | 5643 30303F 60303A |
| 308 420     | 5351 5382  | 5645 30304 60304   |
| 309 430     | 5352 5385  | 5665 30310 60310   |
| 309 +W 430F | 5354 5386  | 5700 30316 60316   |
| 310 431     | 5355 5388  | 5710 30321 60347   |
| 316 431A    | 5358 5389  | 5735 30347 60410   |
| 321 436     | 5360 5392  | 5765 51410 60420   |
| 327 440A    | 5361 5393  | 6270F 51414 60442  |
| 329 440B    | 5362 5394  | 6274F 51416F 60446 |
| 330 440C    | 5363 5526  | 6280C 51420 70310  |
| 331 440F    | 5366 5537  | 6350 51430 70310A  |
| 347 442     | 5369 5610E | 6382 51431 70327   |
| 403 446     | 5370 5616  | 6428 51440A 70330  |
|             | 5372 5621  | 7834 51440B 70331  |
|             | 5373 5628  | 51440C 70446       |
|             | 5375 5630  |                    |

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we'll produce to your specs.  
—in record time!**

THE watchword of CANNON-MUSKEGON is "CONTROL." Careful selection of the finest raw materials . . . rigid melting procedures . . . complete chemical and physical testing facilities, plus closely supervised handling — produce alloys to your most exacting standards. More than 100 special and standard alloy analyses are produced each year.

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FOR IMMEDIATE REFERENCE — write for your personal copy of Cannon-Muskegon's 6-page handbook for metallurgists, giving you data on both UltraMet and MasterMet alloy service.



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offers you both vacuum and  
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a wide variety of cast forms

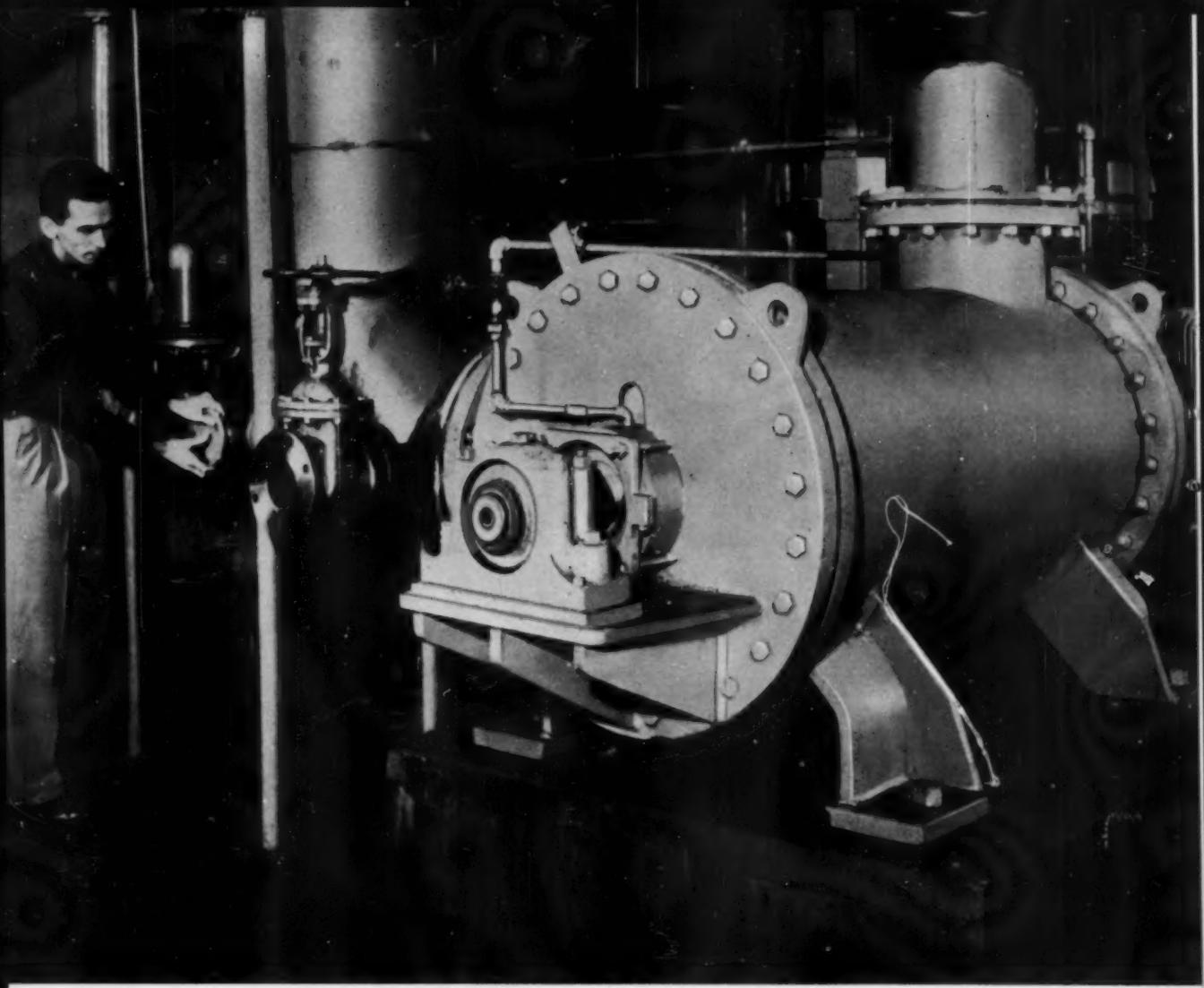


UltraMet alloys are produced in this latest design vacuum melting furnace — production center for a virtually unlimited variety of high temperature, corrosion resistant alloys for severe-stress applications.

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METALLURGICAL SPECIALISTS



Chlorine dioxide mixer in service at the Carolina Division of Riegel Paper Corp. The unit was manufactured by Improved Machinery Inc. It is lined with  $\frac{1}{8}$ " Rem-Cru A-70 titanium sheet.

## Titanium liner gives low-cost protection to a conventional metal

Even a small amount of titanium can protect an entire unit from corrosion damage. Here's an example...

Highly corrosive chlorine dioxide would quickly ruin the conventional material in the mixer shown above. So, titanium, virtually immune to such attack, was used to form a protective liner. Sheets of  $\frac{1}{8}$ " thick Rem-Cru titanium were welded together and formed into a cylinder, which was "rolled in" to fit

the mixer shell tightly. A full year's trouble-free service again shows titanium to be the least expensive metal in terms of service life.

Titanium has many other advantages. It's as strong as steel, for example, yet 44% lighter. And it's a practical way to extend service life by as much as 10, 20, even 50 times. Why not let a qualified Rem-Cru engineer help you work out specific applications.

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At 2200°F, CARBOFRAX® silicon carbide brick transmit 109 BTU/hr., sq. ft. and °F/in. of thickness. That is roughly 11 times the heat conductivity of fireclay and about 70% that of chrome-nickel steels. This conductivity becomes particularly valuable at the higher temperatures which these refractories alone can withstand (up to 3000°F without deformation; under certain conditions even higher). For example, there is increasing use of CARBOFRAX radiant tubes, muffles, retorts, and other structures which may operate at temperatures beyond the limitations of metals.

Seldom, however, are refractories called upon to provide heat conductivity alone. They must also be able to resist corrosion, spalling, cracking, heat shock and abrasion. Ability to carry heavy loads at high temperatures is another requirement often

encountered. These are but a few of the conditions successfully met by super refractories pioneered by Carborundum. Among them, you are almost certain to find answers to your refractory and high-temperature problems. For help, fill in and mail this coupon:

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 Bulletin on Properties of Carborundum's Super Refractories  
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Can you help me?

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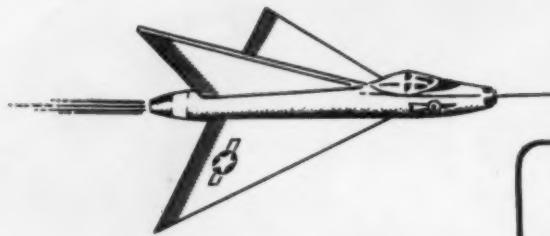
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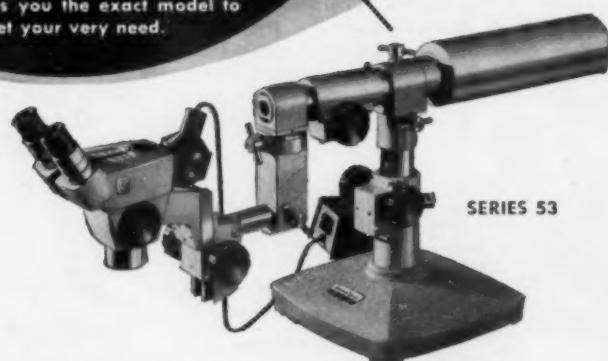
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# MOLY NEWS

CLIMAX MOLYBDENUM COMPANY, 500 FIFTH AVENUE, NEW YORK 36, N. Y.



## Super-Strength Structural Steels Boost Minimum Yield Strengths to 150,000 psi.

Seven steel companies in the U. S. are now producing a group of "Super-Strength Structural Steels" with considerably higher yield strengths than the well-known "High-Strength Low-Alloy" steels.

These Super-Strength steels offer minimum yield strengths ranging from 55,000 to 150,000 psi. And they have other useful properties, depending on composition, including strength at moderate temperatures, toughness at low temperatures, and good wear resistance. Almost all of these steels contain molybdenum as an essential element.

The search for steels with greater yield strengths has gone on for many

years. Before about 1930, carbon steels with a yield point of roughly 30,000 psi were standard for almost all structural purposes. Then came the development of "High-Strength Low-Alloy" steels. They boosted minimum yields into the 50,000 psi range.

Now, the newer Super-Strength Structural Steels are being welcomed by designers, who see in them a way to solve one of their major problems — to minimize weight and size while retaining quality and reliability.

*...For more information on these steels, including their trade names and compositions, circle number 1 on the coupon.*

## Moly's High Hot Strength Shows Promise for Jets and Rockets

Molybdenum-base alloys were described at the 1955 American Rocket Society annual meeting as having the greatest promise for true high-temperature operation.

Missile and powerplant designers are interested in moly mainly for its high temperature strength. Molybdenum-base alloys have been developed with higher useful strength at temperatures over 1600 F than any other presently known metallic material.

The jet propulsion field — including guided missiles and aircraft powered by rocket, ramjet, and turbojet engines — covers a tremendous variety of requirements and service conditions in respect to temperature, atmosphere, amount and type of stress, vibration, thermal shock, and prospective life. Molybdenum's properties make it a logical choice in many cases because it has:

1. High creep and rupture strength.
2. High tensile strength at high temperatures.
3. High modulus of elasticity.
4. A combination of high thermal conductivity, low specific heat, and low expansivity, which minimizes non-uniform temperature distribution and makes molybdenum insensitive to thermal shock.
5. High resistance to erosion by hot gases.
6. High melting point.

It seems safe to conclude that molybdenum-base alloys will become important structural materials in the jet propulsion field. And they will become essential for many parts operating at temperatures in excess of 1600 F.

*...from "Molybdenum for High Strength at High Temperatures," by R. Freeman and J. Briggs, JET PROPULSION, February, 1957.*

For a copy of the complete article, circle number 2 on the coupon.

## Moly Adds Strength and Corrosion Resistance to Titanium

Commercially pure titanium is fairly strong and highly corrosion-resistant. Alloying it, however, substantially increases these useful properties.

Molybdenum may prove to be one of the most useful of the alloying elements for titanium. Studies at Armour Research Foundation, for example, show that when molybdenum is used instead of vanadium, creep properties are greatly improved. At 1020 F, a stress of approximately 20,000 psi produces a creep rate of  $10^{-4}$  in. per in. per hr in Ti-6 Al and Ti-6 Al-4 V, whereas 40,000 psi is required to produce the same creep rate in a Ti-7 Al-3 Mo alloy.

In summary, new alloy development is opening the way for titanium's extensive use in jet engines and air frames. Ti-Al-Mo alloys, for example, give better elevated temperature properties than the Ti-6 Al-4 V alloy now most widely used. And the alloy containing 7% Al and 3% Mo appears particularly promising.

Another Ti-Mo alloy contains 30 to 40% Mo. This alloy is claimed to resist boiling 40% sulphuric acid and boiling 20% hydrochloric acid as well as platinum, tantalum or gold. Such a retained beta alloy is weldable and could be fabricated into sheet. These corrosion-resistant characteristics would add to the value of all-beta Ti-Mo alloys.

*...from "Molybdenum as an Alloy Additive for Titanium," by Harold Marolin, METAL PROGRESS, February, 1957. For a copy of the complete article, circle number 3 on the coupon.*

## Moly Goes to Sea In A Sewer



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Those are good reasons why the County Sanitation District No. 2 of Los Angeles County specifies ASTM A 48, class 40 iron for the rings. In addition to the required 40,000 psi, tensile strength, and 2600 lb transverse strength minimum, (on a 1.2 in. test bar), the bar must be capable of deflecting at least 0.20 in. and the iron must contain at least 0.40% Cr, 0.60% Cu and 0.35% Mo.

Examination of pipe lengths after six years' service showed them in excellent condition. Equally good performance is expected from the most recent installations which extend some 8000 feet into the Pacific Ocean, and are believed to be among the largest in the country.

*...For more information on the contribution of moly to toughness and shock resistance of cast iron, circle number 4 on the coupon.*

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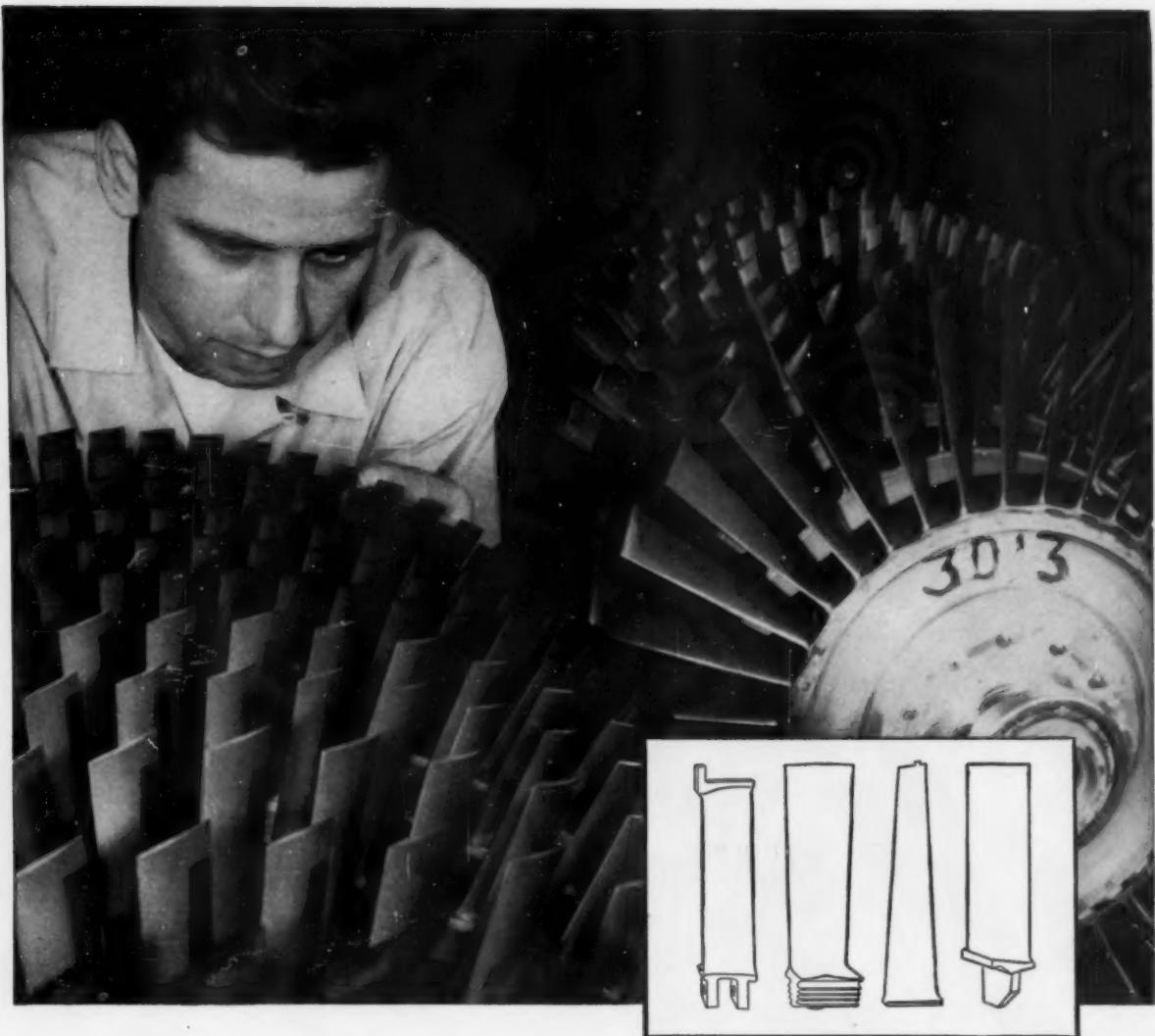
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Crack-Free Chromium also provides:

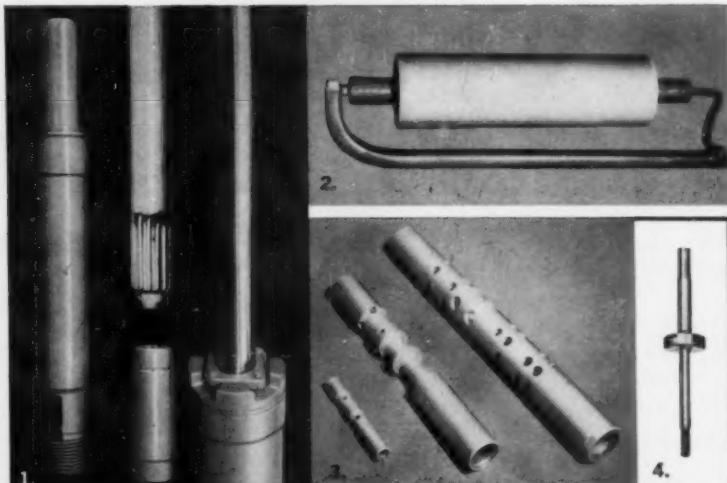
- Increased ductility, so that expansion and contraction cause no cracks.
- Improved non-galling, non-seizing properties.
- Low friction, resistance to wear.
- Hardness (500 to 700 Knoop).
- Excellent leveling action to help cover surface irregularities and reduce grinding needs.
- Protection to the base metal without undercoats.
- A satin matte decorative finish that can be applied directly to zinc die casting as well as steel. It buffs readily to high luster.

Bulletin CFC-2 gives more details on self-regulation and other features.

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### Difficult problems created by heat, wear, corrosion solved by Crack-Free Chromium

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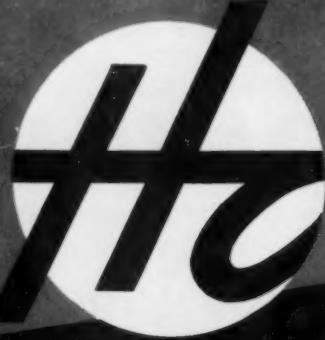
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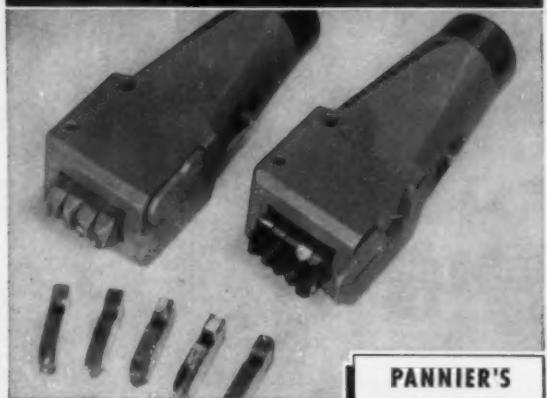
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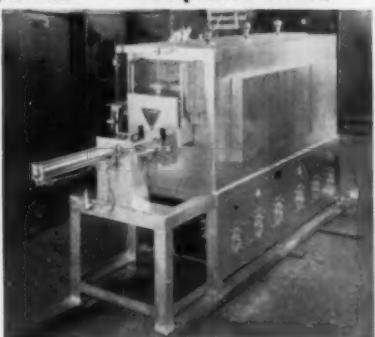
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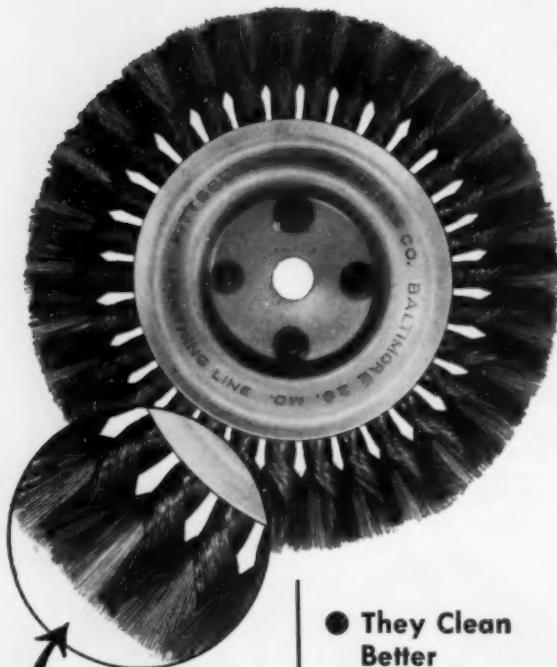
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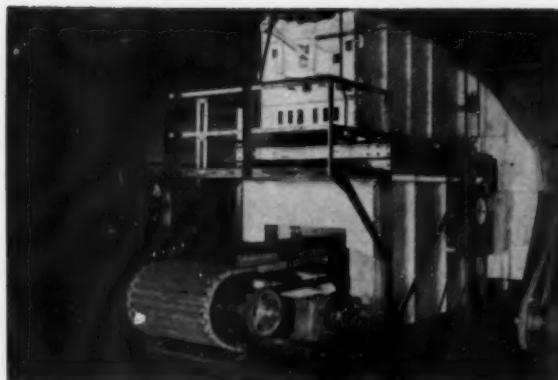
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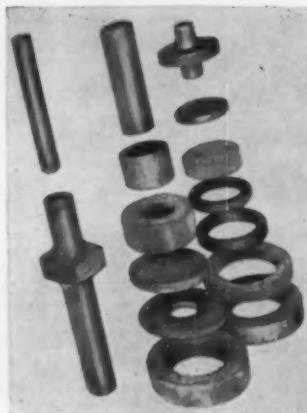


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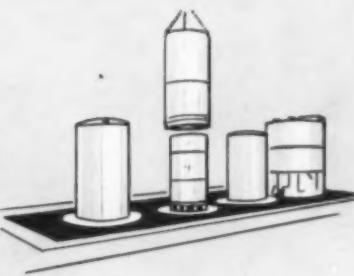
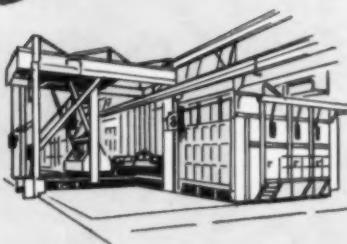
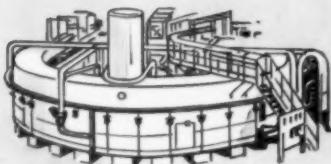
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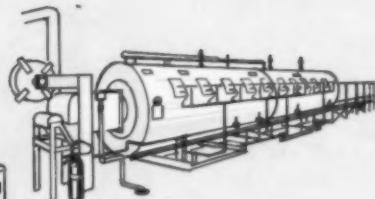
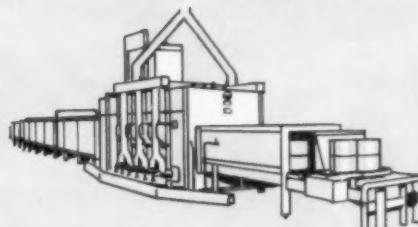
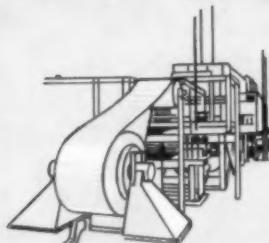
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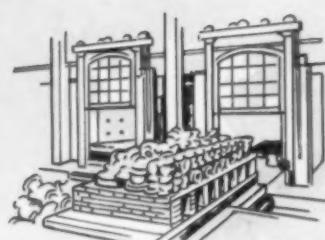
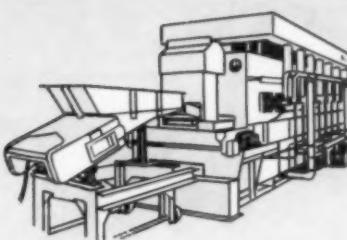
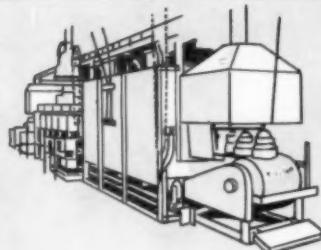
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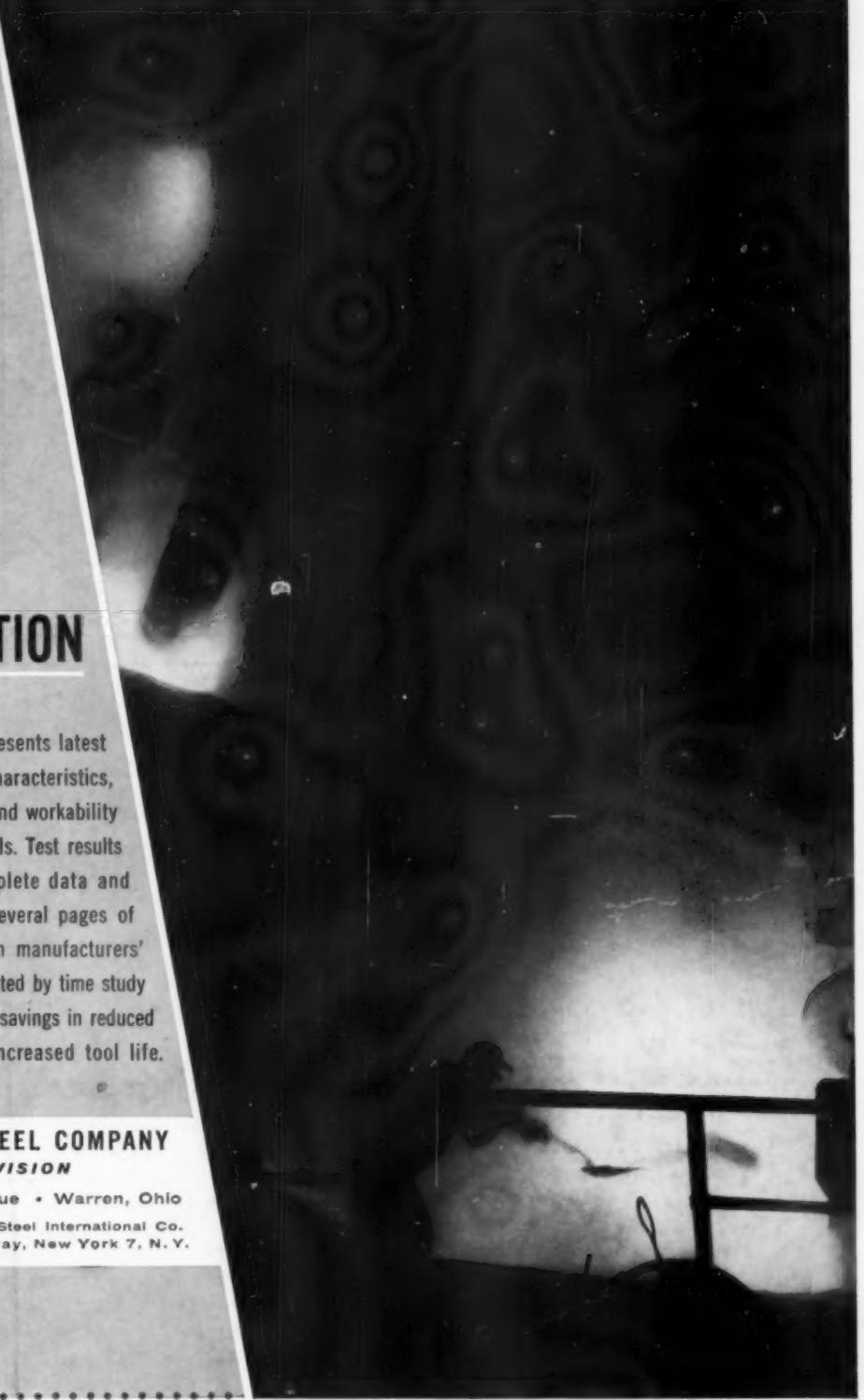


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